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SIGMA XI QUARTERLY

VOL. XXI MARCH, 1933 No. 1

ON FACTS AND FANCIES IN COSMOGONY*

HARLOW SHAPLEY

1. The inadequacy of the standard theories of the origin of various sidereal bodies—the moon, planets, stars, the galaxy—has come to light in recent years and suggests the value of discriminating between facts and fancies in cosmogony; that is, between observation and theory; or better, perhaps, between measures plus reasonable interpretations thereof and speculations that must be based on much more than is measured.

2. These comparisons of observation and theoretical deduction can well begin with the nearest of astronomical bodies and go out to the bounds of the universe.

3. The origin of the moon out of the earth has been heretofore the only well-considered hypothesis of lunar genesis; and for more than a generation the Darwinian form of that hypothesis has been widely accepted. It visualized the birth of the moon from the young earth as the result of the sun's tides and the natural vibrations of the earth's body producing an unstable condition in the then liquid crust. Harold Jeffries of England in recent years has been the chief exponent and developer of this hypothesis; but now Jeffries has himself proved its impossibility. He finds that the internal friction in the earth would not permit the tides to be built up sufficiently high. The primeval earth could have been distorted scarcely more than four per cent. The moon could not have been born from the earth, he believes. And we must resort to another hypothesis, meanwhile noting that we have accumulated a tremendous amount of observational data on the earth and moon without yet providing a convincing clue to the mystery of their origins some billions of years ago.

4. Similarly we have abundant observational data on the planets of the solar system, but the nebular hypothesis yielded to the planetesimal hypothesis and other variants of a tidal evolutionary theory without giving general satisfaction. We now have in our fancies veered back toward an earlier collision origin of the planets from the surface of the sun. But even though that should satisfy the major mystery of planetary origin, it leaves many smaller riddles in the system quite untouched.

5. To advance the observational knowledge of the origin of the earth and other planets, I suggest that researches should be directed to (*a*) a consideration of the general time scale of the universe; (*b*) a study of the place of asteroids and comets in the solar system; (*c*) further exploration of the trans-Neptunian regions where other Pluto-like bodies may be found to throw light on the limits of the solar system; (*d*) investigations of the interior structure of the earth; and (*e*) the increased knowledge of secular changes in the orbital elements of the planets throughout great intervals of time.

* Eleventh annual Sigma Xi address at the meeting of the American Association for the Advancement of Science at Atlantic City, December 28, 1932.

6. If, as seems likely, the tidal theories fail to account satisfactorily for the origin of moon and planets, I propose that we consider the possibility that moon, planets, and sun are all of the same age and that they have arisen in a secondary swirl or eddy of the parental spiral nebula out of which the local galaxy may be supposed to have generated. On this view the moon has not been born from the earth, nor the earth from the sun. Present members of the solar system are merely the survivals of the original heterogeneous population of this particular secondary swirl.

7. In the opinion of many astronomers we are now practically without any theory of evolution of the stars. We have a great burden of facts and reasonable explanations of superficial things about stars—inside facts are lacking.

8. We do not know how galaxies of stars come to exist. We have observations on the general behavior of stars, gravitationally and radiationally. We have actual observations on more than a hundred thousand individual galaxies; we estimate that more than a million are within our present reach, and we fancy that there are hundreds or thousands of millions in the universe. But whether our own galaxy is a simple, typical system or a complex system of two, three, or more galaxies, we cannot tell. In fact, we are just now at the beginning of the accumulation of knowledge of galaxies as galaxies. Within ten years we may have a clearer picture, thanks to the present rapid accumulation of powerful telescopes.

9. The red shift in the spectra of external galaxies is an observed fact. The expanding universe is an hypothesis, because the recession of the galaxies is but one interpretation of the red shift. The expanding universe theory, like the earlier hypotheses of the origin of the moon, planets, and stars, is, however, a valuable contribution to astronomy in that it incites and directs observational activity and interpretation.

10. We have no indication from our recent studies of the distribution of galaxies that our own is of any particular significance, either in stellar and nebular constitution or in position in the universe. With its members unevenly distributed throughout ten million cubic megaparsecs, the metagalaxy we now know shows no falling off in population with distance.

11. Perhaps one of the most important observational contributions in the realm of cosmogony in recent years has been the demonstration of the existence of cosmic meteors. The fact that interstellar space is travelled by particles of solid matter, which must be fragments of larger bodies in a liquid or solid state, argues for an older and more experienced universe than is indicated by the current state of gaseous nebulæ and stars. The important question of the time scale of the universe is involved in the interpretation of shooting stars, as it is also in the evolution of double stars, the origin and evolution of the solar system, the grouping of galaxies throughout the metagalaxy, and the expanding universe hypothesis.

12. We should not worry if some of these fascinating cosmic hypotheses become too-much-emphasized fads throughout the scientific guild, either because of their attractiveness or because of the personality of the proposers; for sooner or later better observations will provide a critical test and the scientist will continue to abandon disproved hypotheses unhesitatingly and unabashed.

MINUTES OF THE MEETING OF THE EXECUTIVE COMMITTEE OF SIGMA XI, ATLANTIC CITY, DECEMBER 28, 1932

The second meeting of the Executive Committee for 1932 was held in Committee Rooms 133-137, Chalfonte-Haddon Hall, December 28, 1932. The meeting was called to order at 2.00 P.M. by Treasurer Pegram. Those present were: Treasurer Pegram, Secretary Ellery, and Mr. Donald H. Sweet; also, by invitation, Dr. Henry B. Ward, past President and past Secretary of the Society.

1. SITUATION AT SMITH, TULANE, AND BUFFALO:

The first item of business was the reviewing of informal petitions which had already been before the Committee. Professor Meyerhoff of Smith College presented additional material about Smith; Doctor Faust of Tulane University about Tulane; and Doctor Hartman and Doctor Atwell about the University of Buffalo. After some discussion, in which members of the Committee asked these representatives of the respective institutions questions about conditions at their institutions, it was

Voted—To refer the supplementary information to the Executive Committee at its stated spring meeting.

2. INFORMAL PETITION FROM WESLEYAN:

The Secretary presented an informal petition from Wesleyan University at Middletown, Connecticut. It was

Voted—That a copy of the informal petition should be sent to all members of the Executive Committee, and that the petition should be considered at the stated spring meeting of the Committee.

3. SITUATION AT DENVER, GEORGIA, AND VIRGINIA POLYTECHNIC INSTITUTE:

Additional information was presented from the University of Denver, the University of Georgia, and the Virginia Polytechnic Institute. It was

Voted—To refer this additional information to the stated spring meeting of the Committee.

4. UNIVERSITY OF HAWAII:

Report was presented from Professor Stewart, who was official visitor to the university, and letters from the Stanford, California, and University of Washington chapters. It was

Voted—To present the official visitors' report and the chapter letters to the stated spring meeting of the Committee.

5. GEORGE WASHINGTON UNIVERSITY:

Reports were presented from the official visitors, Professors Pegram and True, and a letter from the North Carolina Chapter. It was

Voted—To refer the reports and the letter to the stated spring meeting of the Committee.

6. PRINTED PETITIONS:

Printed petitions were presented from Duke University and the University of California at Los Angeles. It was

Voted—To present these printed petitions to the Convention with recommendation to favorable action.

7. CERTIFICATES OF AWARD FOR RESEARCH:

The Secretary presented seventeen candidates from various institutions in the departments of chemistry, physics, and biology, for a certificate of award for research, in accordance with the action of the 1931 Convention, which authorized the Executive Committee to make such awards to undergraduates in institutions where there is no chapter of Sigma Xi. It was

Voted—To recommend that the President of Sigma Xi appoint special subcommittees to read the theses submitted, and to report to the stated spring meeting of the Committee.

8. AMENDMENT TO THE CONSTITUTION:

At the 1931 Convention it was suggested that the Executive Committee might be empowered to elect as associates of the Society promising students in institutions where there is no chapter, and to provide for their initiation. The matter was brought to the attention of the Committee, and after considerable discussion it was

Voted—To postpone until the 1933 Convention a recommendation that the Constitution of the Society be amended to empower the Executive Committee to elect as associates promising students in institutions where there is no chapter.

9. SEMI-CENTENNIAL:

The Secretary presented an invitation from President Rush Rhees, of the University of Rochester, and from the Rochester Chapter, to hold the semi-centennial of the Society in Rochester at the time of the summer meeting of the A. A. A. S. in 1936. It was

Voted—That the Secretary be instructed to express to President Rhees and the Rochester Chapter the appreciation of the Committee and the Society of the gracious and generous invitation, and to inform both President Rhees and the Chapter that the Society had already accepted an invitation from the Provost of Cornell University and the Cornell Chapter to hold the semi-centennial in Ithaca.

10. BINDING EARLY PUBLICATIONS:

Professor Ward referred to a previous action of the Executive Committee which authorized him to collect and bind early publications of the Society which antedated the present SIGMA XI QUARTERLY, and to write an introduction to the collection. It was

Voted—To confirm the previous action of the Executive Committee, and to authorize Professor Ward to expend not more than $100.00 in the preparation of these volumes of the early publications of Sigma Xi.

11. INFLUENCE ON EDUCATION OF HONOR SOCIETIES IN COLLEGES AND UNIVERSITIES:

The Secretary presented letters from the United States Department of the Interior (Educational Section), inviting the Society to join with Phi Beta Kappa and Phi Kappa Phi and other similar organizations in a study of the work and influence of so-called honor societies in educational institutions in this country. It was

Voted—To authorize the Secretary to participate in such a study on the part of Sigma Xi, provided the study did not involve any expense to the Society.

12. THE QUARTERLY:

The Secretary called the attention of the Committee to the expense of publishing the QUARTERLY, and presented bids from various publishers, including the present publisher. It was

Voted—To authorize the Secretary to seek further bids, and to award the contract to the firm which could publish the QUARTERLY in the best form at the least expense.

13. DIPLOMAS FOR MEMBERS AND ASSOCIATES:

The Secretary announced that the new diplomas for members and associates approved by the 1931 Convention were now ready for distribution, and that they could be provided at the cost of nine cents per diploma in any quantity, from a single diploma to 100 or more.

14. LETTER FROM RENSSELAER POLYTECHNIC INSTITUTE:

The Secretary presented a letter from the assistant director of the Rensselaer Polytechnic Institute, in which the writer set forth the curriculum of a new course offered by the Institute which included a combination of the social and natural sciences. The letter stated that while students in this course were not specializing in science as that term is accepted by the Society of Sigma Xi, the students were doing in those sciences work which might later be a basis for research work in some particular field. The letter asked whether those students would be eligible to associateship in Sigma Xi, although during their undergraduate days they had not particularly emphasized work in any one scientific field. It was

Voted—To instruct the Secretary to call attention to the action of the Executive Committee at its meeting in April, 1930, as follows:

> The list of sciences given in the March, 1928, issue of the QUARTERLY with the addition of Psychology should be accepted as indicating the fields of investigation recognized by Sigma Xi.
>
> The sciences so listed are: Mathematics, Physics, Chemistry, Astronomy, Sciences of the Earth, Biology in its various branches, including Psychology, Anthropology, Medicine in its various branches, and Engineering in its various branches.

and further, that

> The sciences given in the above list and others closely allied thereto represent, in general, the fields of investigation which it is the purpose of Sigma Xi to recognize; and that in case any chapter is in doubt regarding the eligibility of investigators in other fields, before election takes place the chapter should ascertain and be guided by the opinion of the Executive Committee or of some of the officers authorized by the Executive Committee to act for it in such matters.

15. ADJOURNMENT:

The meeting adjourned at 4.00 P.M.

EDWARD ELLERY, *Secretary*

PROCEEDINGS OF THE THIRTY-THIRD CONVENTION OF THE SIGMA XI

The Thirty-third Convention of the Society of the Sigma Xi was held in Committee Rooms 133-137, Chalfonte-Haddon Hall, Atlantic City, December 28, 1932.

1. CALL TO ORDER:

Secretary Ellery called the business session to order at 4.00 P.M. He announced that owing to serious illness in his family President Wilson was unable to be present at the Convention, and asked for nominations for temporary presiding officer. By vote of the Convention, Treas. George B. Pegram was named as presiding officer, and took the chair.

2. RESOLUTION OF SYMPATHY FOR DOCTOR WILSON:

The Convention recommended that the Secretary write to President Wilson, expressing the regret of the delegates that Doctor Wilson could not be present, and assuring him of the sincere sympathy of the Society in the sorry experience through which he is passing.

3. COMMITTEE ON CREDENTIALS:

Professor Pegram announced the Committee on Credentials, as follows: Prof. W. P. Davey, Pennsylvania State College, chairman; Prof. W. S. Kimball, Michigan State College; and Dr. F. A. Hartman, University of Buffalo.

4. REPORT OF THE COMMITTEE ON CREDENTIALS:

The Committee received the credentials of delegates, and reported the following chapters and clubs represented:

Chapter	*Delegates*	*Chapter*	*Delegates*
Cornell	F. K. Richtmyer	Pennsylvania	F. H. Safford
	A. J. Heinicke		R. H. True*
Rensselaer	R. A. Patterson	Brown	A. A. Bennett
	G. K. Palsgrove		W. H. Snell
Union	Edward Ellery		A. M. Banta*
Kansas	Not represented	Iowa	J. H. Bodine
Yale	John Nicholas	Stanford	C. H. Danforth
	G. Baitsell	California	J. F. Daniels*
Minnesota	R. A. Gortner		B. R. Hoagland*
Nebraska	H. O. Werner	Columbia	Shirley L. Quimby*
Ohio State	Dwight M. De Long	Chicago	Fay-Cooper Cole
	J. H. Weaver		C. J. Chamberlain

* Reported as appointed, but not present at Convention.

Chapter	*Delegates*
Michigan	O. S. Duffendack
Illinois	Not represented
Case	Not represented
Indiana	H. T. Davis*
	Will Scott*
Missouri	Mary J. Guthrie
	Carl G. Vinson
Colorado	A. J. Kempner
Northwestern	Leslie B. Arey
	Oliver J. Lee*
Syracuse	F. F. Decker
	V. A. Young
Wisconsin	Not represented
U. of Wash.	Not represented
Worcester	R. A. Beth
Purdue	H. E. Enders
	J. J. Davis*
Washington U.	Not represented
Dist. of Col.	Paul Bartsch
Texas	Not represented
Mayo Found.	T. B. Magath
North Carolina	J. N. Couch
North Dakota	Not represented
Iowa State Col.	J. W. Woodrow*
	P. E. Brown*
	A. L. Bakke
Rutgers	H. E. Starr
	J. B. Allison
	R. d'E. Atkinson
McGill	Not represented
Kentucky	W. S. Webb
	W. A. Price
Idaho	C. W. Hungerford
Swarthmore	Arnold Dresden
Oregon	Not represented

Chapter	*Delegates*
Virginia	I. F. Lewis*
	C. C. Speidel*
Johns Hopkins	J. C. Hubbard*
	A. Cohen
Calif. Inst. of Tech.	Not represented
New York	H. W. Stunkard
Cincinnati	Not represented
Michigan State	W. S. Kimball
Arizona	F. Shreve
Lehigh	C. R. Richards*
	Tomlinson Fort*
	Max Petersen*
Maryland	R. Bamford
	A. F. Woods
	H. J. Beaumont
Kansas State	Mary T. Harman
Col. of Med., U. of Ill.	Not represented
Penn. State	W. P. Davey
Oklahoma	W. Schriever
State Col. of Washington	Not represented
Wyoming	O. H. Rechard
	John W. Scott
Rochester	E. F. Adolph
	O. R. McCoy
	Arthur S. Gale*
	Miss Sabra J. Hook
Pittsburgh	Davenport Hooker
Harvard	George H. Parker*
	Harlow Shapley*
Western Res.	J. C. Gray
Princeton	George H. Shull
	Louis A. Turner

Club Delegates

Club	*Delegates*
Southern Calif.	Not represented
Carleton	Not represented
Denver	Not represented
Oregon State Agr. College	Not represented
West Virginia	P. D. Strausbaugh
	C. R. Orton

Club	*Delegates*
Maine	K. S. Rice
Florida	W. B. Tisdale
Colorado Agr. College	Not represented
South Dakota	Not represented
Louisiana State	Not represented
Alabama	E. B. Carmichael

* Reported as appointed, but not present at Convention.

Club	*Delegates*
Arkansas	Not represented
Calif. at Davis	W. W. Robbins*
	E. E. Wilson*
	F. J. Veihmeyer
	H. A. Jones*
Utah	Not represented
Clark	Not represented
St. Louis	Not represented
Connecticut Agr. College	Not represented
Miami	R. L. Edwards
Georgia	J. W. Nuttycombe*
	T. J. Harrold*
Bucknell	Not represented
Duke	George T. Hargitt
Buffalo	F. A. Hartman*
Okla. A. & M.	Not represented
California at Los Angeles	S. J. Barnett
Montana State	J. R. Parker*
N. Dak. Agr.	Not represented
Texas Tech.	Not represented
U. of Montana	Not represented
Virginia Poly.	Not represented
Wichita	Not represented

The following officers were present:

Treasurer: George B. Pegram, Columbia
Secretary: Edward Ellery, Union
Executive Committee: Donald H. Sweet, Alumni Committee

5. MINUTES OF PROCEEDINGS OF THE THIRTY-SECOND CONVENTION:

The account of the proceedings of the Thirty-second Convention of the Society at New Orleans, December 29, 1931, published in the March, 1932, QUARTERLY, was approved as printed.

6. REPORT OF PRESIDENT:

The Secretary presented the report of President Wilson. (See page 12, this issue.)

7. REPORT OF SECRETARY:

The annual report of the Secretary was presented. (See page 15, this issue.)

8. REPORT OF TREASURER:

The Treasurer presented his annual report. (See page 17, this issue.)

9. AMENDMENT TO THE CONSTITUTION:

At the 1931 Convention the Cornell Chapter proposed the following amendment to the Constitution:

Resolved, that the Constitution of the Society be so amended as to create a new class of membership, namely, that of Members-for-Life, a distinction which may be accorded by any chapter which sees fit to do so, to active members in good standing who have been members for forty years or

* Reported as appointed, but not present at Convention.

longer; or to active members in good standing who have attained the age of seventy years, irrespective of the length of their membership; these Members-for-Life to retain all the privileges of members, but to be released from the obligation of further payment of dues.

The proposal was referred to the Executive Committee for report at the Thirty-third Convention. The Executive Committee presented the following report:

a. The term "Life Member" is inappropriate, since all members of Sigma Xi are members for life.

b. Members of Sigma Xi do not pay dues to the national organization.

c. It is within the province of a chapter to honor any of the chapter's members by an exemption from payment of chapter dues, if the chapter so wishes.

d. The designation of "retired member" is appropriate for those of its members whom a chapter may desire to honor.

After some discussion by various delegates, it was

Voted—That the amendent be not approved.

10. The Thirty-fourth Convention:

The Secretary presented a letter from Doctor Roos, secretary of the A. A. A. S., regarding the summer meeting of the A. A. A. S., designated for Chicago in 1933, and stated that while the Constitution empowers the Executive Committee of the Society to name the place and time of the annual Convention, the Executive Committee desired an expression of opinion from the Convention as to whether the Thirty-fourth Convention of the Society should be held in the summer of 1933 in Chicago, rather than at the usual time, namely in December in Boston. There was considerable discussion by delegates, and it was finally

Voted—To recommend that the Thirty-fourth Convention be held in connection with the A. A. A. S. meetings in Boston in 1933, and that the Executive Committee at its discretion should arrange for a special meeting of the Society to be held in Chicago at the time of the A. A. A. S. meetings scheduled for that city in 1933.

11. The Semi-centennial:

The Secretary called attention to the action of the Executive Committee taken at its spring meeting regarding the celebration of the fiftieth anniversary of the Society.

Proposals from the Cornell Chapter have been received by the Executive Committee that the semi-centennial of the Society be celebrated in Ithaca in the summer of 1936 in connection with the summer meeting of the A. A. A. S. scheduled for Rochester. The Provost of Cornell University also has presented an invitation to Sigma Xi to come to Cornell at that time. The

Executive Committee of the A. A. A. S. has expressed itself in favor of a plan to make the semi-cenntennial of Sigma Xi a part of the program of the Rochester meeting, and is prepared to assign one day of the Convention week for the celebration.

The Secretary stated that the Executive Committee desired an expression of opinion from the Convention regarding the place and the time of the semi-centennial celebration. Many opinions were expressed. It was finally

Voted—That the semi-centennial be held in Ithaca in June, 1936, under the joint auspices of the Cornell Chapter and Cornell University, and in connection with the summer meeting of the A. A. A. S., provided the summer meeting of the A. A. A. S. is held in Rochester in that year.

12. PRINTED PETITIONS:

The Secretary presented printed petitions from Duke University and the University of California at Los Angeles, stating that they were presented with the recommendation of the Executive Committee to favorable action. It was

Voted—*a.* That the petition from Duke University be granted.

b. That the petition from the University of California at Los Angeles be granted.

13. PROMOTION OF RESEARCH:

The Secretary called attention of the Convention to the action of the Executive Committee taken at the spring meeting, as follows:

> That it is desirable that from now on the income from the invested funds of the Society be segregated for use in direct recognition or promotion of research, and that such use begin in the form of an award at the time of the semi-centennial celebration in 1936.

He stated that the Executive Committee desired expressions of opinion from the Convention regarding that action. Various opinions were given. The sense of the Convention seemed to be that the award should take the form of a recognition of research rather than of a prize for research accomplished, and that the funds of the Society should be used to further research already in progress.

14. ANNUAL ASSESSMENT:

The Treasurer called attention of the Society to the fact that the Treasurer's report showed a surplus of receipts over expenses, and that in his judgment the Society might barely meet the 1933 budget by reducing the annual assessment from seventy-five cents per enrolled member and associate to fifty cents for the year 1933. After considerable discussion by the delegates, it was finally

Voted—That an assessment, due January 1, 1933, be levied on each chapter at the rate of seventy-five cents per enrolled member and associate for the fiscal year 1933.

15. Election of Officers:

The Nominating Committee, consisting of C. E. McClung, Pennsylvania, chairman; Prof. Harlow Shapley, Harvard; and Dr. Victor C. Myers, Western Reserve, presented the following report:

For member of the Executive Committee, to serve for the ensuing five years: Prof. A. O. Leuschner, University of California.

For member of the Alumni Committee, to serve for the ensuing five years: Mr. Donald H. Sweet, of Chicago.

It was

Voted—That the Secretary be empowered to cast a ballot for the officers as named. The presiding officer announced the election of the officers as named.

16. Adjournment:

After announcement of the annual dinner, the Convention adjourned at 6.10 P.M.

The Annual Dinner

Delegates and members and guests, to the number of seventy, assembled at 6.30 P.M. in the Rutland Room of the Haddon Hall for the annual dinner.

The Eleventh Annual Lecture

After the dinner the company adjourned to the Municipal Auditorium for the eleventh annual Sigma Xi lecture, given by Prof. Harlow Shapley, director of the Astronomical Observatory at Harvard University, on "Fact and Fancy in Cosmogony." An abstract of the lecture is given as the opening article in this issue of the Quarterly. The lecture was illustrated by lantern slides. The audience was one of the largest ever assembled at these annual Sigma Xi events, numbering some twelve hundred people.

PRESIDENT'S REPORT

Your President reports the activities of the Society for 1932, as follows:

1. During the year two chapters have been added to the Society. The Western Reserve Chapter was installed February 24, 1932, with Professor Cole of the Executive Committee as the installing officer, taking the place of the President of the Society who was prevented by illness from attending. The Princeton Chapter was installed March 19, 1932, with the President of the Society as the installing officer.

2. A Sigma Xi Club has been organized at Yenching University in Peiping, China, with Prof. W. H. Adolph, president; Mr. Y. C. Mei, vice-president, and Mr. A. P. T. Sah, secretary and treasurer. Professor Adolph is professor of bio-chemistry, and was elected to Sigma Xi at the University of Pennsylvania Chapter in 1912. Mr. Mei is president of Tsinghua University, and was elected to Sigma Xi at Worcester Polytechnic Institute in 1914. Mr. Sah, also of Worcester Polytechnic Institute (1925), is professor of physics at

Tsinghua University. The club numbers twenty-four members. At Peiping there are six large universities, the Peking Union Medical College (Rockefeller Foundation) and several research institutions. Thus the Sigma Xi spirit is being carried to all quarters of the globe.

3. Our Society now has sixty chapters, with a total of nearly 12,000 members and associates. There are thirty-one clubs, but no record is available of the number of members and associates enrolled in them. With the connection of the clubs to the national organization constantly growing closer, it may be wise in the near future to make club enrollment a part of the permanent records of the Society.

4. The total membership of the Society (including associates) is approximately 26,000.

5. The Executive Committee has given careful consideration to informal petitions from groups of the Society's members and associates at thirteen colleges and universities. Pursuant to vote of the Committee, the President appointed official visitors to make personal survey of conditions at one of the institutions, and presents to you today, with recommendation to favorable action, formal printed petitions from Duke University and the University of California at Los Angeles. The Committee postponed action in the case of the ten others.

6. The Executive Committee reports as follows on the proposal, made at the Thirty-second Convention and referred to the Committee for report, that a new class of members be created, namely, members-for-life:

a. The term "Life Member" is inappropriate, since all members of Sigma Xi are members for life.

b. Members of Sigma Xi do not pay dues to the national organization.

c. It is within the province of a chapter to honor any of the chapter's members by an exemption from payment of chapter dues, if the chapter so wishes.

d. The designation of "retired member" is appropriate for those of its members whom a chapter may desire to honor.

Minnesota Chapter suggests the title "honorary member" for this group.

7. In view of the special emphasis to be given the summer meeting of the A. A. A. S. in Chicago in 1933, and in response to an invitation from the Committee of Arrangements for that meeting, the Executive Committee recommends that this Convention vote to hold the next annual meeting in Chicago in 1933 instead of in December.

8. The Society will celebrate its semi-centennial in 1936. At the spring meeting the Executive Committee considered at length a possible appropriate program to mark this important event. Dean Richtmyer of Cornell, and Doctor Roos, secretary of the A. A. A. S., participated in the discussion. The Committee passed the following vote:

a. That the Executive Committee recommend to the Convention that the invitation from the Cornell Chapter and Cornell University to hold the semi-centennial celebration in Ithaca in the summer of 1936 be accepted.

b. That the exact time of the month of June and the exact day of the week for the celebration be left for decision to the Executive Committee of the A. A. A. S., the Cornell Chapter and Cornell University, and the Executive Committee of Sigma Xi.

c. That a national committee on the celebration, consisting of a representative of each chapter chosen by the chapter, be appointed at once, to work with the sub-committee in perfecting the arrangements for the celebration.

d. That a tentative program for the celebration be submitted to the consideration of the Executive Committee at its spring meeting, 1933.

9. In compliance with the action of the Thirty-second Convention, which authorized the Executive Committee to present certificates of award for excellent work in physics, chemistry, and biology to students in institutions where there is no chapter of Sigma Xi, letters were sent to about 125 different institutions scattered over a broad area, inviting them to submit the names and qualifications and theses of exceptional students in the fields named. Returns from these letters are now coming in. The Executive Committee, at its meeting just prior to this Convention, received recommendations from several institutions, will give them careful study, and report the awards at the next Convention.

10. The invested funds of the Society now amount to approximately $18,000. The securities are carried on the treasurer's account at cost. The Executive Committee has voted that:

> It is desirable that from now on the income from the invested funds of the Society be segregated for use in direct recognition or promotion of research, and that such use begin in the form of an award at the time of the semi-centennial celebration in 1936.

11. The Committee on Award of Grants-in-aid (Professor Shapley of Harvard, and Professor Calkins of Columbia), distributed a total of $1,900 to eight applicants. The amount contributed this year by the alumni members and associates was considerable under the amounts of previous years. The report of the Committee is given in detail in the September issue of the QUARTERLY.

The business and influence of the Society grows in volume and importance as the years pass. Comments and suggestions from chapters and individuals are urgently asked and cordially welcomed. During the year, both at the spring meeting and by voluminous correspondence, the national board of officers has given generously of its time and counsel to the many matters involved in the administration of a constantly growing organization. The President takes this occasion to acknowledge the indebtedness of the Society to them all.

LOUIS B. WILSON, *President*

REPORT OF THE SECRETARY

1. The work of the Secretary's office grows in volume with the increase in the number of chapters and consequent enlargement of enrollment lists of members and associates and of newly elected members and associates. The Society gains in numbers of members and associates at the rate of approximately 1,500 per year. Obviously that involves more labor and time given to typing cards and stencils for the alphabetical and geographical files—in addition to the constant work of keeping the active address list up-to-date.

By expending extra labor at no very large additional cost, the Secretary is able to report that index cards and address stencils for newly elected members for 1932 are complete and filed, for all lists received up to the date of compiling this report (December 20). The work of correcting chapter enrollment lists lags a little. We have still to correct our files for twelve chapters. (At the time of publication, March, 1933, this work is complete.)

To date (December 20) the office has had no index cards of newly elected members and associates from the following chapters: Iowa, Columbia, Syracuse, Washington University, Kentucky, Oregon, California Institute of Technology, College of Medicine (University of Illinois), and Princeton. At the time of publication, March, 1933, all of the above chapters, except Iowa and Princeton, have sent in index cards for new members and associates.)

Hereafter it will not be necessary for chapter secretaries to send in their complete enrollment lists. They will be asked to submit only changes of addresses, additions of names not on prior list, or omissions of names on prior list. This will reduce the labor of the Secretary's office. We can then keep the records more nearly up-to-date than is possible now.

2. There is always the usual amount of correspondence to be handled, some of it routine, much of it concerning new situations which are bound to crop up in an expanding organization. Except under most unusual circumstances, every inquiry is answered the day it reaches the Secretary. All insignia orders are transmitted to the official jeweler within a few hours of their receipt. The infrequent delays which have arisen occasionally in the delivery of an emblem to the purchaser have been due to causes outside the Secretary's office, more particularly in recent months to a reduction in the working hours in the plant of the jeweler.

3. The new certificates of membership and associateship authorized by the Executive Committee and approved at the last Convention, are now ready for distribution. The cost is slightly above that of the old style—nine cents each instead of five cents. But as a partial offset, the Secretary's office is now in a position to supply them in any number, from a single certificate to lots of fifty or more. It will be recalled that the former diplomas were supplied in packages of fifty only.

4. Chapter and club secretaries have done well in submitting reports of activities for the year. Reports have been received from forty-four of the sixty chapters, and fifteen of the thirty-one clubs.

Chapters which have not reported are: Cornell, Yale, Iowa, Columbia, Chicago, Illinois, Indiana, Syracuse, University of Washington, Washington University, Texas, California Institute of Technology, Arizona, Pennsylvania State, and State College of Washington.

The Secretary knows very well that the chapters from which reports have not been sent have been active. It would not only complete files in the central office of the Society and be generally helpful and interesting if all chapters would submit reports, but it would greatly assist the historian of the Society when writing of the forward movements in the organization during the last twenty-five years.

5. Following are items of interests from reports received:

a. Referring to a recent complaint that engineers have no part in Sigma Xi, it is to be stated that during the last academic year five chapters included engineers or engineering topics in their programs, namely, Michigan, Worcester, New York University, Missouri, and California.

b. Six chapters presented foreign scientists to their membership and public, as follows:

Brown—Prof. J. S. B. Haldane, England
Harvard—Sir James Jeans, England
Northwestern—Dr. Willem de Sitter, Leyden Observatory
McGill—Dr. Willem de Sitter, Leyden Observatory
Stanford—Dr. Willem de Sitter, Leyden Observatory
Swarthmore—Dr. Willem de Sitter, Leyden Observatory
Dr. Charles Singer, England

c. As is to be expected, the character of the programs varies. They can be roughly classified as follows:

1. Inspection of research under way at the institution: Michigan, Pennsylvania, Rochester.

2. Reports of researches by members: Kansas, Union, Ohio State, Rutgers, Pennsylvania, Lehigh, Wyoming.

3. Programs given by newly elected associates: Kentucky.

4. Joint meetings with other groups: District of Columbia with Phi Beta Kappa and Washington Academy of Science; Pennsylvania with Phi Beta Kappa; Rochester with Rochester Academy of Science; Mayo Foundation with Sigma Xi Club at Carleton College; Oregon with State College at Corvallis and with Phi Beta Kappa; Missouri with Phi Beta Kappa.

5. Interdepartmental meetings: Swarthmore.

6. Reports of thesis work by students: Worcester.

d. Symposia on a single topic: Minnesota presented four lectures on Evolution and Civilization, which were attended by a total of 12,700 people.

e. Research prizes are awarded by Pennsylvania, Colorado, Virginia (two prizes—one for graduate in biology, and one for best contribution by

member of the faculty), and Minnesota; Wisconsin, a special Sigma Xi loan funds for graduate students; Wyoming has plan under consideration.

f. Special Sigma Xi day at the University of Rochester: Program permitted scientific and non-scientific members of the university and public of Rochester to become acquainted with the methods and purposes of scientific research. Sigma Xi members took the occasion to become acquainted with each other's researches. During the afternoon, exhibitions of current scientific research were on display and exhibitors gave brief talks. In the morning an illustrated lecture was given, intended especially for children. In the evening a formal dinner attended by members and guests was followed by an address.

EDWARD ELLERY, *Secretary*

REPORT OF THE TREASURER

The 1932 assessments of all chapters except the California Institute of Technology were paid within the year. The payment from that chapter was received in January, 1933.

RECEIPTS

Cash on hand, January 1, 1932	$ 6,866.24	
Chapter assessments for 1932	5,486.06	
Chapter assessments for 1931, arrears	83.00	
Initiation fees for 1932	2,498.13	
Initiation fees for 1931, arrears	552.00	
Chapter assessments, advance for 1933	187.50	
Sale of QUARTERLY	1.75	
Installation fees	100.00	
Interest on investments	897.50	
Overpayments of assessments for 1932	77.75	
Surplus on dinner for 1931	8.25	
Sale of insignia	813.80	$17,574.98

DISBURSEMENTS

Secretary's office (total—$3,820.75):		
Assistants	$ 1,292.00	
Office—general	308.35	
Alumni circularization	420.40	
Secretary's stipend	1,800.00	
Treasurer's office (total—$173.25):		
Clerical assistance	150.00	
Stamps and telegrams	13.25	
Auditing 1931 books	10.00	
Officers' traveling expenses	987.61	
QUARTERLY (four issues)	2,434.71	
Engrossing charters	120.70	

Certificate samples	43.55	
Refunds on assessments	77.75	
Government tax on checks	.68	
Loaned Alumni Fund	97.28	
1 U. S. Treasury 4¼% bond	999.06	
1 Public Service Gas & Elec. Co. 4% bond	857.50	
1 New York Telephone Co. 4½% bond	997.50	
1 U. S. Treasury 4% bond	999.06	
Interest on above bonds, accrued	51.31	
Cash on hand, December 31, 1932	5,914.27	$17,574.90

Investment Account—General

The current market value of most of these bonds is much below the purchase price as listed below, particularly for the railroad bonds. All the companies continue to pay interest on their bonds except the St. Louis and San Francisco Railway, which is in receivership.

$1,000 Amer. Tel. & Tel. 5½% bond at	$ 1,037.44	
$1,000 Amer. Tel. & Tel. 5½% bond at	991.94	
$1,000 Consolidated Gas of New York 5½% bond at	1,002.90	
$1,000 St. Louis & San Francisco Railway 4% bond at	796.35	
$1,000 Baltimore & Ohio Railway 5% bond at	955.00	
$1,000 Pacific Gas & Electric Co. 5½% bond at	1,045.00	
$1,000 Philadelphia Co. 5% bond at	979.50	
$1,000 Erie Railroad Co. 5% bond at	947.00	
$1,000 Southern Railway Co. 6% bond at	1,152.00	
$1,000 Western Electric Co. 5% bond at	1,029.50	
$1,000 Philadelphia Co. 5% bond at	997.00	
$1,000 New York Central 6% bond at	1,032.00	
$1,000 Canadian Pacific 5% bond at	1,010.00	
$1,000 Amer. Tel. & Tel. 5% bond at	1,077.50	
$1,000 U. S. Treasury 4% bond at	999.06	
$1,000 U. S. Treasury 4¼% bond at	999.06	
$1,000 New York Telephone Co. 4½% bond at	997.50	
$1,000 Public Service Elec. & Gas. Co. 4% bond at	857.50	$17,900.25

Alumni Fund

RECEIPTS

Cash on hand, January 1, 1932	$ 599.54	
Receipts from subscriptions	1,320.68	
Unused portion of grant returned by Paul Weatherwax	60.00	
Refund by C. L. Fluke, overpayment of grant	50.00	
Interest on investments	90.00	
Borrowed from General Fund	97.28	$ 2,217.50

DISBURSEMENTS

Research:		
Thomas Large, 1931-32	$ 100.00	
Claude R. Kellogg, 1931-32	250.00	
Paul Weatherwax, 1931-32	150.00	
C. L. Fluke, 1931-32	400.00	
Mildred Hebel, 1931-32	100.00	
Charles E. Braun, 1931-32	100.00	
Rachel Hoffstadt, 1932-33	125.00	
Ruth Marshall, 1932-33	100.00	
Walter F. Loehwing, 1932-33	200.00	
Carney Landis, 1932-33	220.50	
Charles Vincent Taylor, 1932-33	250.00	
Seward E. Owen, 1932-33	60.00	
Charles E. Braun, 1932-33	100.00	$ 2,155.50
Overpayment to C. L. Fluke	50.00	
Non-negotiable checks	12.00	
Cash on hand, December 31, 1932	0,000.00	$ 2,217.50

INVESTMENT ACCOUNT—ALUMNI FUND

(Securities carried at cost)

$1,000 Southern Pacific Co. 4½% bond at	$ 905.75	
$1,000 Southern Pacific Co. 4½% bond at	907.00	$ 1,812.75

GEORGE B. PEGRAM, *Treasurer*

December 31, 1932.

We have audited the accounts of the Treasurer of the Society of Sigma Xi for the year ending December 31, 1932, and certify that the income shown by the books of the Treasurer has been duly accounted for, that payments have been properly vouched and that the balance sheet and accounts submitted contain a true statement of the financial condition of the Society. We have also examined the securities in the hands of the Treasurer and find the following bonds: $1,000 Amer. Tel. & Tel.; $1,000 Amer. Tel. & Tel.; $1,000 Consolidated Gas of New York; $1,000 St. Louis & San Francisco Railway; $1,000 Baltimore & Ohio Railway; $1,000 Pacific Gas & Electric Co.; $1,000 Philadelphia Co.; $1,000 Erie Railroad Co.; $1,000 Southern Railway Co.; $1,000 Western Electric Co.; $1,000 Philadelphia Co.; $1,000 New York Central; $1,000 Canadian Pacific; $1,000 Amer. Tel. & Tel.; $1,000 U. S. Treasury; $1,000 U. S. Treasury; $1,000 New York Telephone Co.; $1,000 Public Service Elec. & Gas Co.; $1,000 Southern Pacific; $1,000 Southern Pacific.

L. BRETT
J. T. FINNERAN
Auditors

CHILD DEVELOPMENT AND THE COMING GENERATION

FLORENCE L. GOODENOUGH
Institute of Child Welfare, University of Minnesota

Two years ago in the first Symposium of this series, Doctor Scammon outlined the major features of the physical growth of the body during childhood. Tonight I shall take up certain aspects of mental growth, using the term in its broad sense to include the changes that take place in the social and emotional behavior of the child as well as in his intellectual characteristics. It is true that we are as yet unable to trace the course of mental development with anything approaching the degree of precision and assurance that is possible in the field of physical growth. In his measurements of bodily form and structure the anatomist not only has the great advantage of dealing with material objects that can be seen, felt, and handled, but he is able to express the results of his investigations in terms of absolute units, such as inches and pounds, whose significance is independent of the particular objects measured and which convey a similar meaning throughout the civilized world. The units of measurement employed by the psychologist in his studies of behavior have no such universality of meaning. In many cases they are nothing more than rather crude descriptive characterizations of forms of behavior that bear little surface resemblance to each other and whose association in a series bearing a common label can be justified only by reason of the empirical discovery that they develop along parallel lines and their progress seems to be accelerated or retarded by a a common series of factors. Thus one of our best-known "intelligence tests" includes at different levels such apparently diverse tasks as copying a square, naming colors, repeating a series of digits backward, giving definitions, arranging weights in order of magnitude, pointing out absurdities in a series of impossible statements, and drawing designs from memory. Our warrant for including such a variety of performances as parts of a single "test" is to be found first in the fact that their growth seems to be associated in such a way that a child who is backward in one is likely to be backward in all, while children who show accelerated development along one of these lines usually show a similar precocity with reference to the others; and secondly, in the fact that in spite of their apparent diversity, each of these performances has been found to have some value in forecasting the kind of behavior for which the test is designed. Because human behavior changes so greatly in kind from one level of development to another, one of the most difficult problems with which the student of mental development is faced is that of determining which forms of behavior show similar growth-patterns and may, therefore, be classed together for purposes of study.

Equally as difficult as the problem of selection and classification of behavior patterns is the question of the units in terms of which varying levels of performance can be expressed. The student of behavior has no ready-prepared scales

of magnitude, calibrated in equal units, which he may apply to his data. Behavior is not measured in pounds and ounces, and even the application of the time-scale serves but a limited function. Although we may feel that a certain *kind* of performance is "better" or "more mature" than another, or that this task is easier or more difficult than that, we have no very direct way of saying by *how much* the performances differ in excellence or the tasks in difficulty. Yet some such quantitative statement becomes necessary if the statement is to take on any degree of scientific precision. In the absence of any measurement expressed in terms of the behavior itself, we resort to measurements expressed in terms of the individuals whose behavior is observed. By examination and record of the behavior of large numbers of cases we ascertain such facts as the following: The average level or kind of performance on a given task made by children of different ages, the percentage of individuals of a given age who equal or exceed a given level of performance, or the percentage of individuals who succeed with each of two tasks whose difficulty is to be compared. From data of this kind we are able, by means of various statistical devices, to arrange our data in an orderly fashion and to express the results of our investigations in fairly precise terms. For example, after having ascertained that certain defined forms of behavior grow and develop according to a common pattern and show a common relationship to other forms of behavior that are commonly regarded as having an "intellectual" basis, such as school success, breadth and profundity of general information, etc., we may set up a series of tasks involving the display of the behavior in question and ascertain what level of success on each of the tasks is attained by the average child at each successive year of life. By grouping together the various performances characteristic of each age we may construct what is commonly known as an "intelligence test," arranged according to the "year scale" principle. If we then apply this test to other children we are able to describe their mental levels in terms of the age of children to whom their performances most nearly correspond. We speak of this as the "mental age." Since the mental age to be expected of any child obviously depends upon his chronological age, it is customary to express the relationship between the two in terms of the quotient obtained by dividing the mental age by the chronological age. This is the famous "intelligence quotient" or IQ. For convenience of expression it is customary to state the quotient as a percentage, omitting the decimal point. Thus a child of eight years whose performance on the test under consideration is equal to that of the average child of ten is said to have a mental age of ten years and an IQ of 125. If his performance is only equal to that of a child of six, his IQ is 75. Within certain limits, the IQ has the same significance whatever the age of the child, and is thus a more generalized measure than the mental age alone.

A number of other methods of quantifying the results of tests are in more or less common use, but it is not necessary to consider them here, since they are all based upon the common principle of utilizing the individual differences among large groups of subjects in their performances on these tests as a means for securing a quantitative expression or measurement of the performance of others.

An intelligence test, so-called, does not then measure "just any kind" of intelligence. Instead it measures with more or less accuracy the subject's ability along a number of carefully defined lines, performance in which has been shown by actual experiment to be useful in predicting school success or other types of achievement which, by common consent, are thought of as "intellectual." Here as elsewhere, precision of definition and measurement is achieved by limitation of the range of meaning. "Intelligence" meaning "score on the X— intelligence test" is undoubtedly a narrower concept than "intelligence" meaning "whatever my hearers may think intelligence to be," just as the statement "John Doe is seventy-three inches tall" has a narrower range of possible meanings than the statement, "John Doe is a big man." The latter expression may refer to Doe's latitude as well as to his longitude, or may even, in colloquial usage, include his financial and political standing as well. In like manner, the popular concept of intelligence is too vague and varies too greatly from one individual to another to be of much service in scientific work. With all its limitations and in part by very reason of these limitations, the test method has opened the way to a type of scientific investigation that could not well be carried on without its use.

Individual Differences in Intelligence-test Standing.—Every-day observation tells us that even among children of the same age, marked differences in mental ability can be noted. Five-year-old children, for example, range all the way from the occasional profound idiot who can neither walk nor speak and who must be fed and cared for like an infant to the equally rare child of exceptional endowment who at the age of five reads Dickens and Stevenson with pleasure and understanding. Between these extremes are to be found the great majority of children. Their numbers steadily increase as we pass from the level of the idiot toward the point that represents the average degree of ability for a given age, after which the proportions again fall off as the higher levels of development are reached.

Although observation tells us that such differences in ability exist, the use of appropriate mental tests enables us to express their frequency and extent in a more precise fashion than can be done by observation alone. Repeated investigations have shown that when mental tests are given to large numbers of unselected children of the same age, the distribution of abilities corresponds very closely to the normal probability curve, with the majority of cases clustering about the average for the group and the numbers decreasing toward each extreme. For example, in a study of nearly twenty thousand children in Kansas City, Missouri, who were tested at the time of school entrance[1] it was found that while approximately 31 percent had mental ages that fell within four months of their chronological ages, the number who varied considerably from the average was great enough to constitute a real problem of school administration. Almost 1 percent of these children had mental ages below four years; nearly as many were mentally equal to the average child of eight years or older.

The question may well be raised at this point: What of it? What significance has the IQ earned on an intelligence test for the child's success in

the practical affairs of life? It is unnecessary to dwell upon the very obvious fact that abstract intelligence, even if it were far more perfectly measured than our present crude tests enable us to do, is only one of many factors making for successful adjustment. That it is a factor of considerable importance, and that the results obtained even by the use of our present imperfect methods of measurement are not without meaning has been shown repeatedly. I shall take time here to point out only a few of the typical findings. Figure 1 shows the relationship between intelligence-test scores and age-grade placement in school. The data are based upon 263 elementary school children, all of whom were between eleven and twelve years of age at the time of testing. The mental

	Grade								
Mental age	I	II	III	IV	V	VI	VII	VIII	Total
18	..	..	..	..	..	..	1	..	1
17	..	..	..	..	..	..	3	1	4
16	..	..	..	..	..	1	2	..	3
15	..	..	..	..	2	5	6	1	14
14	..	..	..	1	6	13	2	..	22
13	..	..	..	3	12	18	1	..	34
12	..	..	1	2	22	12	..	..	37
11	..	..	2	10	42	6	..	..	60
10	..	..	6	15	20	1	..	..	42
9	..	2	3	14	6	..	..	..	25
8	1	5	6	2	..	..	..	..	14
7	1	1	3	..	..	..	..	..	5
6	1	..	..	..	..	..	..	..	1
5	1	..	..	..	..	..	..	..	1
Total	4	8	21	47	110	56	15	2	263

FIG. 1. GRADE LOCATION OF 263 ELEVEN-YEAR-OLDS BY STANDFORD-BINET MENTAL AGE

These children were all eleven years old, chronologically. Correlation is .81.

(Reproduced by permission of Houghton Mifflin Co. from *The Intelligence of School Children* by L. M. Terman.)

ages vary from five to eighteen years. The greater range of the mental ages in this group is for the most part due to the fact that the children are older. It has been repeatedly shown that for tests of the kind used here, the variability of the mental ages increases in proportion to the age of the subjects.

These eleven-year-old children are scattered all the way from the first to the eighth grade in school. Examination of Figure 1 shows a distinct relationship between grade location and mental age as determined by the tests used. The correlation between grade-placement and mental age for this group is +.81.

Since education and occupation are somewhat related, it is not surprising to find that among adults, intelligence-test standing affords a partial index to the general kind of occupation at which a person is likely to succeed. A fact less generally known is that some degree of segregation along intellectual lines can be observed, not only among adults of different occupational groups, but in their children as well. The extent of this differentiation is shown in Figure 2.

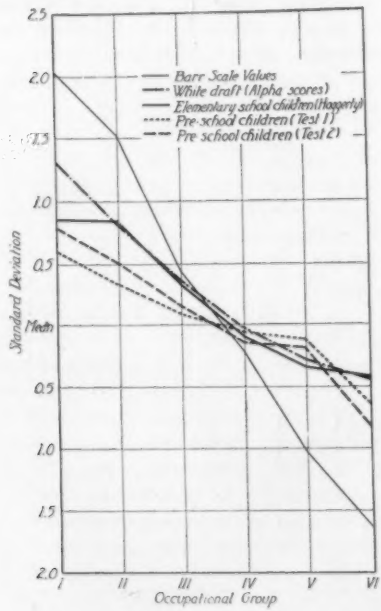

FIG. 2. INTELLIGENCE OF PRE-SCHOOL CHILDREN

(Reproduced by permission of the *American Journal of Psychology* from "The Relation of the Intelligence of Pre-school Children to the Occupation of their Fathers," by F. L. Goodenough, *American Journal Psychology*, 1928, 40, p. 289.)

In this figure the findings from several studies have been reduced to similar terms for purposes of comparison. The Roman numerals along the abscissa refer to the successive groups in a classification of urban occupations that has been found useful in a number of studies carried out at the University of Minnesota. The classificatory scheme is modeled in part upon the Barr scale for occupational intelligence and the Taussig industrial classification. Group I includes the professional classes—doctors, lawyers, etc.; Group II the semiprofessional, such as accountants and draughtsmen, and major business men. Group III is made up of persons engaged in the skilled trades—carpenters, electricians, mechanics, etc., also clerks, bookkeepers, and minor business men. Group IV includes the less skilled trades and the majority of the factory workers; Group V the slightly skilled workers such as truck-drivers, milkmen, and janitors; while Group VI is made up of the day laborers.

The broken line shows the mean scores on the Alpha intelligence test made by the men in the draft army when classified according to the occupations in which they had been engaged in civilian life. The heavy solid line shows the mean scores made by approximatetly six thousand elementary school children in New York State, when classified according to the occupation of their fathers. These data are based upon a report by Haggerty and Nash. The two lines of short dashes show the scores made by a group of 380 Minneapolis children between the ages of eighteen and fifty-four months on two successive administrations of the Kuhlman-Binet tests.

In every group the scores show a successive decrease from one occupational class to the other. This, of course, is true only of the averages for the groups;

there is much variation from these averages among the individual cases. There are children of day laborers whose performance exceeds the average for the professional classes and *vice versa*. In spite of these exceptions, the general trend of the results is clear.

Similar results have been obtained by many other investigators both in this country and abroad. In addition to paternal occupation, such measures as the Sims score card for the study of socio-economic status; the Chapin scale for rating living-room equipment, the Williams scale for rating homes, the education of the parents, and in a few studies, the intelligence-test scores made by the parents have been compared with the test standing of the children. Positive correlations have been reported in all cases with which I am acquainted.

The discovery of such a clear relationship between the socio-economic status of the home and the intelligence of the children has given rise to much discussion and to a number of investigations planned in the hope of disentangling, at least in part, the relative contributions of hereditary and environmental factors to the determination of mental growth. Since most children are reared by their own parents, data such as those just reported may be interpreted in either of two ways. A superior home environment may in itself *cause* intellectual superiority in children by providing keener intellectual stimulation and greater opportunity to acquire information. On the other hand, it may be argued that superior social status is on the average a *result* of superior mental ability on the part of the parents who have achieved it, and that this ability is transmitted to their children by direct biological heredity in the same manner as hair color, eye color, or other physical traits. Among ordinary children reared by their own parents, superior heredity is so generally accompanied by superior environment and *vice versa* that it is difficult, if not impossible, to determine which factor has the more potent effect upon the intellectual development of children.

It is impossible for me to give more than a brief indication of the various ways by which this problem has been attacked. Undoubtedly the most significant results that have appeared to date is to be found in the studies of foster children carried out at Stanford and Chicago Universities. The Stanford investigation[2] is based upon a study of 214 children between the ages of five and fourteen years who had been adopted into foster homes before the age of twelve months. Intelligence tests were given to both children and foster parents, and a large amount of supplementary data on the characteristics of the foster home together with such facts as could be obtained regarding the abilities of the true parents were secured. For comparison with the results obtained for the foster children, a similar study was made of a group of 105 children reared in their own homes.

Small relationships were found between the intelligence-test scores of the foster parents and their foster children, also between the scores of the children and the level of the foster homes. These correlations, however, were of much smaller magnitude than the corresponding figures for the children reared by their own parents. By the use of partial correlation methods, Burks comes to the conclusion that environmental influences alone account for approximately

17 percent of the IQ variance found in the general population, the remainder being ascribed to heredity.

The study by Freeman and his coworkers at Chicago,[3] although making use of a similar method leads to somewhat different conclusions. Freeman, however, did not confine his cases to children adopted during infancy. His subjects, therefore, had a more varied background of experience than had the group studied by Burks. This has the advantage of permitting a greater number of comparisons, but also greatly increases the danger that experimental findings may be invalidated through the operation of disturbing factors such as differential selection.

Freeman found that the intellectual resemblance between foster children and true children of the foster parents or that between unrelated foster children reared in the same home was of about the same magnitude as that between own brothers and sisters reared in different foster homes, but in both cases the correlations were significantly lower than those usually found for true siblings reared together. He found also that for a small group of children who were tested both before placement in a foster home and again some years afterward, an improvement in test standing was usually found. The gain was greatest among the children placed in foster homes of high cultural level.

The average intelligence quotient found for the children in the Stanford group was 107; for the Chicago group 95. In the Chicago study, an inverse relationship was found between age at placement in the foster home and IQ. Children placed under the age of two years had an average IQ of 102; those placed between the ages of two and five years, 98; those placed after the age of five, 88. A review of all the findings leads Freeman to the conclusion that heredity and environment are about equally effective in determining individual differences in mental ability.

In attempting to evaluate the two studies, one is led inevitably to consider the possibility of differential selection in placement. If it should be found that child-placing agencies consciously or unconsciously tend to place children of superior hereditary background in homes of superior culture, the finding of a positive relationship between the level of the foster home and the intelligence of the foster child loses much of its significance. If the more intelligent and cultured parents choose to adopt children during infancy, while those of lower socio-economic status are more likely to prefer children somewhat older who require less care and will sooner arrive at an age at which they may be expected to become useful around the home, a relationship between age at placement and the level of the foster home is necessitated; while if it can be assumed further that prospective foster parents tend to select children who appear bright and alert, rather than those whose behavior suggests mental backwardness, even though their judgment is often in error there will still be a likelihood that the children who are left in the care of the child-placing agencies for long periods will on the average be less capable mentally than those who are placed early.

A large number of the children placed in foster homes are illegitimate. It has usually been found that unmarried mothers on the average rank below the level of the general population in intelligence. There are wide individual dif-

ferences, however, that make it necessary to ascertain whether or not illegitimate children placed in foster homes can be regarded as a fair sample of illegitimate children in general. A recent study by Leahy[4] carried out in cooperation with the Minnesota Children's Bureau affords a reasonably conclusive answer to this question. The data are based on records of over thirteen thousand cases, which is by far the largest number entering into any study up to the present time. Moreover, since under the Minnesota Children's Code, all illegitimate children, whatever their social status, come under the jurisdiction of the State until permanent legal disposition of the case has been made, the group studied is far more representative of the general illegitimate population than those commonly available for studies of this kind. A statistical comparison of the hereditary background of the illegitimate children in this group who were placed for adoption with that of the children retained by their own mothers showed a constant superiority of the adoptive group in every factor for which information was available. These factors included education and occupation of the child's mother, of the maternal grandparents and of the alleged father, as well as a number of other facts generally found to be related to intellectual level. It was further shown that the children placed for adoption at an early age were clearly superior in family background to those placed later.

This study shows clearly that as a group, illegitimate children adopted into foster homes are decidedly superior in hereditary background to illegitimate children in general. All the figures lead to the expectation of an intellectual endowment well up to the average of the general population for these adopted children who unquestionably represent the cream of the illegitimate group. We cannot, therefore, assume that the high average intelligence quotients reported by Burks (whose cases were all placed before the age of twelve months and approximately 75 percent of whom were illegitimate), and in the youngest group of cases studied by Freeman, are necessarily attributable to the superior environment provided by the foster homes.

A second line of evidence is provided by comparison of the resemblances of identical and fraternal twins. It is generally recognized that twins are of two types—monozygotic or identical twins who develop from the division of a single fertilized ovum, are always of the same sex, and resemble each other very closely in physical appearance; and dizygotic or fraternal twins who develop from separate cells, may be either of the same or unlike sex and whose physical resemblance is no greater than that of ordinary brothers and sisters. The inheritance of monozygotic twins is identical, while dizygotic twins may inherit unequally from the paternal and maternal lines, just as do ordinary brothers and sisters. The difference in the extent to which the two types of twins resemble each other in their intellectual characteristics may, therefore, be interpreted as measuring the extent to which identical heredity can increase resemblance above that resulting from partial similarity of heredity. Among twins reared in the same home, the environment may be regarded as equally similar for both groups.

A number of studies on this problem have been carried out, with closely similar results. In general it may be said that the scores of identical twins on

tests of intelligence and achievement agree almost as closely as do those of the same individual when tested on different occasions, while those of fraternal twins show about the same degree of resemblance as do those of ordinary siblings. Such tests of personality traits and emotional characteristics as are available commonly show much smaller differences in the correlations for the two groups. This suggests that environment and training are more effective in determining the personality traits of an individual than in increasing his intellectual capacity.

In consideration of all the evidence, it seems practically impossible to deny the importance of inherited factors in determining the intellectual level of the individual. It seems probable, also, that the environment and training to which the child is subjected may modify his capacities to some extent, though the evidence here is rather less conclusive.

We cannot afford to ignore the practical import of these findings. If the child's ability is to a large extent determined by factors that are beyond our control once he is with us, we must see to it that the demands made upon him are commensurate with his talents. Many an individual of mediocre ability has had his personality warped and his attitude toward life permanently embittered by being continually forced into situations that he is unable to meets successfully. On the other hand, superior endowment in no way guarantees superior achievement, and still less does it insure personal happiness or successful relationships with one's fellows. This fact is well brought out by the recent follow-up study of the Stanford group of gifted children. Although by far the greatest number of these children who are now approaching maturity are fulfilling their early promise in a notable manner, there are a number who are making very poor use of their ability, or whose social adjustments are far from satisfactory. In the majority of instances the difficulties seem attributable to environmental handicaps. Terman's comment here is worth noting:

"That the victims of such unfavorable circumstances carry on bravely and hopefully does not make the spectacle any less touching to the sympathetic observer. In a majority of cases, we believe, the fight will be won, though sometimes at heavy cost and not without suffering and scars. In other cases the obstacles may prove too great to surmount. The theory that "genius will out" no difference how oppressive the environment is just nonsense. In any community at any time one can find genius that is being starved or warped or killed by influences that are too powerful or too insidious to be combated successfully."[5]

But intelligence is only one of the many aspects of child development and behavior in which we are interested. Equally important is it that we know something about the laws of motor development, of the development of language, and of social and emotional behavior patterns, and the way in which all these factors are associated in the total personality of the child. In the time that remains to me this evening I shall try to describe very briefly some of the ways in which problems of the kind just outlined are being attacked.

Motor Development.—A number of attempts have been made to develop comprehensive series of motor tests by means of which individuals may be

classified according to their general level of motor development in a way analagous to that employed for the study of general intellectual development. Thus far these attempts have met with but little success. So far as we have been able to determine, motor skills or activities of widely different types or involving widely separated muscle groups seem to bear but little relationship to each other. A person may be very dexterous in the use of his hands and yet be very clumsy in his general bodily balance. He may be able to move his fingers with unusual rapidity in a tapping test, and yet be a very slow runner. The development of motor ability seems, therefore, to be specific rather than general, nor do the various motor skills whose development has been studied show, as a rule, much relationship to general intellectual development. An extensive study of the motor development of infants has been carried out by Shirley at Minnesota. This investigation represents one aspect of a much broader study of the development of infants during the first two years of life. A group of twenty-five infants were followed by means of weekly visits to the home during the first year of life and bi-weekly visits during the second year. At each visit an extensive series of observations and measurements was made. The method employed for the study of walking was as follows: Beginning at the age of four months the infant, whose feet had previously been covered with olive oil, was supported in a standing position over a strip of white paper in such a way that his feet could just touch the paper. As progressive stepping movements were made the examiner who was supporting the child moved with him along the paper. By this method it was possible to study progress in walking from a period much earlier than that at which children are able to support their own weight. By dusting the sheets with powdered charcoal the oily footprints of the infant were brought out clearly for later study.

Figure 3 shows the median distance traversed in a one-minute period by children of different ages. You will note that the chart is divided into four panels. This division indicates four major phases of walking that were observed to occur rather uniformly in all the children studied. First, there is a period of early incoordinated stepping with some forward progress. During this stage the child makes frequent stepping movements, often on tiptoe and, as a rule, shows only intermittent attempts to support his own weight. This period lasts on the average from about the seventeenth to the twenty-ninth week. Note that the average amount of forward progress during this period is greater than that made during the period immediately following which extends roughly from the twenty-ninth to the forty-second week. The second general period may be characterized as the period of standing. During this stage there is often a considerable amount of swaying from one side to the other, but relatively few attempts at stepping. The child's attention and effort seems to be centered upon maintaining the upright position.

The third stage is characterized as the period of walking with support. During this stage, which extends on the average from the forty-second to the sixty-fifth week the child walks with steadily increasing precision and speed when led by the hand. The final stage, that of walking without support, blends rather smoothly into the period of walking when led and shows rapid progress

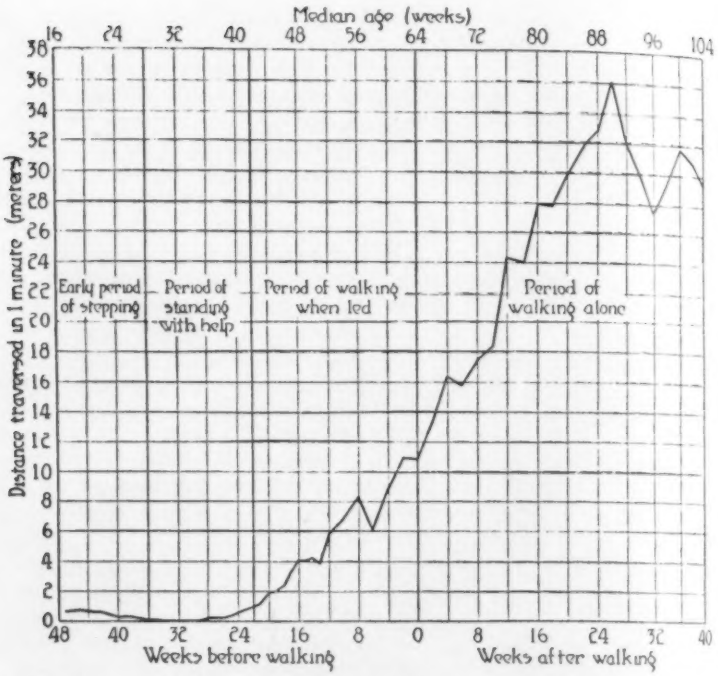
Median age (weeks)
16 24 32 40 48 56 64 72 80 88 96 104
Distance traversed in 1 minute (meters)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38
Early period of stepping
Period of standing with help
Period of walking when led
Period of walking alone
48 40 32 24 16 8 0 8 16 24 32 40
Weeks before walking
Weeks after walking

FIG. 3. MEDIAN DISTANCE TRAVERSED IN A ONE-MINUTE INTERVAL OF WALKING

(Reproduced by permission of the University of Minnesota Press from *The First Two Years*, Vol. I, by Mary Shirley.)

both in the median number of steps taken and in the distance traversed in a given period of time.

Figure 4 shows the same stages of progress as appear in Figure 3, but in this case the unit of measure employed is the median number of steps taken in one minute without reference to the amount of forward progression. The outstanding difference between this curve and the one preceding it lies in the clearer differentiation of the period of early stepping from the later period of standing.

The tapping test is a well-known method of measuring speed of arm and hand movements. Several procedures are in common use, some of which make use chiefly of whole arm movements, others chiefly of wrist movements, others of finger movements. An attempt was made[6] to ascertain whether or not any difference in functional maturity of these muscle groups could be observed. Kindergarten children and college students were used for comparison. Time limits and procedure were identical for both groups of subjects and for all types of tapping. Two trials on consecutive days were given in each case and

the percentage of the adult speed attained by the children in each type of movement was ascertained.

A fairly steady progression was found in the ratio of child speed to adult speed in passing from the small to the large muscle groups. The greatest maturity was shown in the whole arm movements, wrist movements ranked second, index and middle fingers next, while the little finger lagged decidedly behind the others.

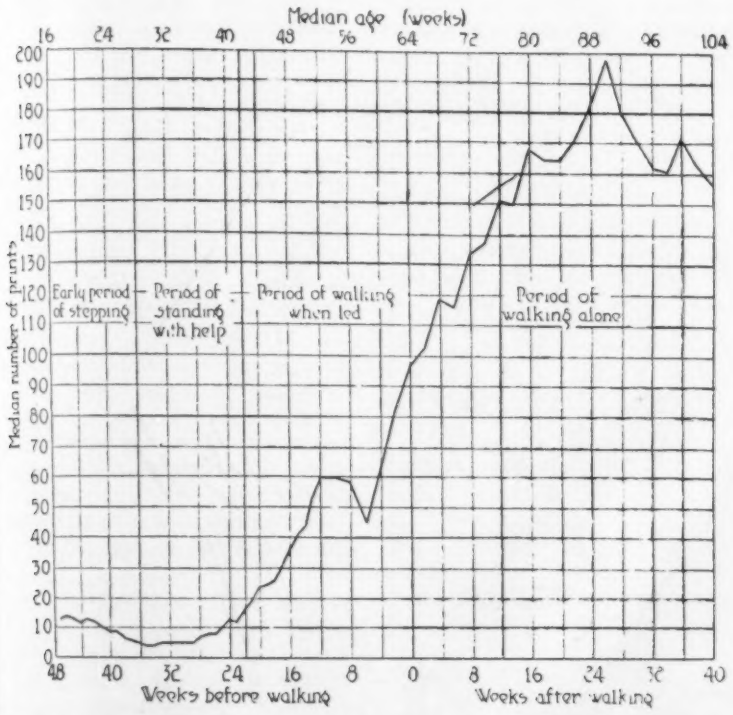
Median age (weeks)
16 24 32 40 48 56 64 72 80 88 96 104
Median number of prints
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
Early period of stepping
Period of standing with help
Period of walking when led
Period of walking alone
48 40 32 24 16 8 0 8 16 24 32 40
Weeks before walking
Weeks after walking

FIG. 4. MEDIAN NUMBER OF PRINTS OBTAINED IN A ONE-MINUTE INTERVAL OF WALKING (SMOOTHED)

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The effect of hand preferences was clearly shown both in the adult group and among the children. Right-handed people tap much more rapidly with the right than with the left hand, while the reverse is true of the left handed. It is interesting and significant to note that at least in this type of performance, hand preference seemed to be as well established at the age of five years as at the college level. The proportionate difference between the speed of the

preferred and non-preferred hand was about equally marked for both groups of subjects.

At how early an age does handedness become apparent? Further investigation is needed before this question can be answered with assurance, but a study by Lippmann throws some light on the matter. His subjects were 178 infants between the ages of four and one-half and twelve months. A number of these infants were observed more than once at different ages, making a total of 382 observations. The method employed was to seat the child on a table or on his mother's lap and then to offer him an interesting object and note with which hand he reached for it. Care was taken always to present the object exactly in the mid-line of the child's body. The age-changes in the percentage of time each hand was used in reaching is shown in Figure 5.

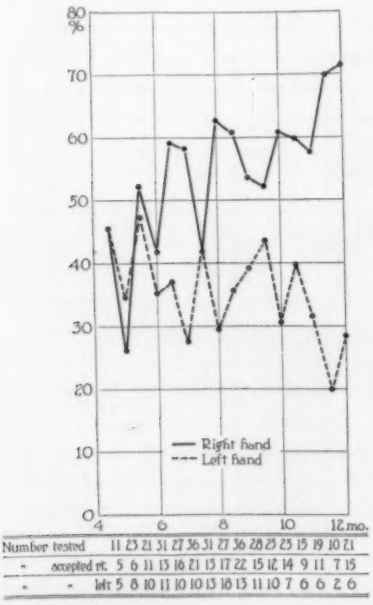

FIG. 5. CURVES SHOWING PERCENTAGE DISTRIBUTION OF REACHING WITH THE RIGHT AND LEFT HAND FOR THE FIRST OBJECT OFFERED

(Reproduced by permission of Clark University Press from "Certain Behavior Responses in Early Infancy" by H. S. Lippmann. *Pedagogical Seminary and Journal Genetic Psychology*, 1927, 34, p. 438.)

The children under six months of age reach about equally often with either hand. About the age of six months a distinct preference for the right hand can be noted. The difference in the frequency of use of the two hands increases steadily up to the age of twelve months. Whether or not this preferential use of the right hand is due to some innate tendency, or whether it is due at least in part to conscious or unconscious training on the part of the parents is not apparent from these results. It is clear, however, that the establishment of hand preferences goes on at a rather rapid rate during the second half year of life.

Language Development.—The rapid development of speech is one of the most striking phenomena of child development. Perhaps no other form of behavior has equal significance for the study of broad relationships in the intellectual, social, and emotional reactions of the child to his environment. A frequent type of language investigation has for its object the determination of the average size of vocabulary at different ages. The most accurate norms available today are those of Smith[7], who, by a combination of the observational method for very young children and a simple vocabulary test for those somewhat older, succeeded in developing a series of

standards that may be regarded as at least more nearly representative of the accomplishment of the average child at successive ages than any other available figures. According to Smith, at the age of one year the mean number of words used is three, at two years the number has increased to 272, at three years it is 896, at four years 1,540, at five years 2,072, and at six years 2,562 words. After the child has learned to read, the growth in vocabulary is even more rapid, till by the age of eighteen the best figures indicate that the average vocabulary is between 15,000 and 19,000 words. These figures, it should be noted, refer to the number of words whose meaning is known. The number of words actually used in everyday speech is much smaller. As might be expected the size of vocabulary is closely related to intellectual status. The relationship of size of vocabulary to the socio-economic background of the home is even greater than the corresponding difference in the intellectual status of children from different cultural backgrounds.

Not only the size of vocabulary but the average length and complexity of the sentences used shows fairly rapid development with age. McCarthy has studied this and other aspects of language development in children between the ages of eighteen and fifty-four months. Her method was to secure fifty consecutive language responses from each child studied, and to find the average length of sentence at each age. Figure 6 shows these averages by age and sexes separately.

The curve rises fairly steadily from age to age. In general the girls seem to be somewhat in advance of the boys. This tendency for a slight superiority of the female sex in linguistic skills has appeared rather generally in most investigations, regardless of the ages involved.

There are other ways of studying the child's language behavior that throw much light upon his personality traits and the development of his social reactions. An exceedingly interesting method of studying the functional aspects of language has been developed by Piaget[8] at Geneva. A modified form of Piaget's method was used by McCarthy in her study. Piaget divides all language responses into two main classes: Egocentric speech and socialized speech. Each of these main categories is sub-divided into a number of smaller classes. By collecting verbatim records of children's conversation over a period of time and comparing the percentage of the different types of responses used by dif-

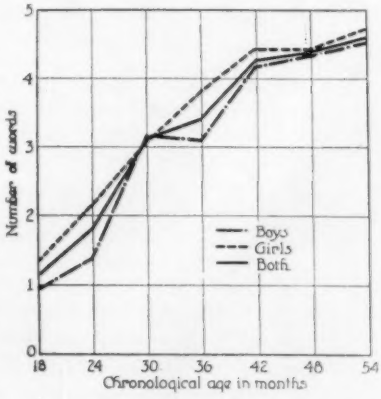

FIG. 6. MEAN LENGTH OF RESPONSE BY CA AND SEX

(Reproduced by permission of the University of Minnesota Press from *Language Development of the Preschool Child* by Dorothea McCarthy.)

ferent children it is possible to gain considerable information as to their personality characteristics. Time does not permit me to show the age changes in the functional aspects of language in detail. An example of the findings is shown in Figure 7 which shows the age changes found by McCarthy in the proportion of the total number of responses which fall under the head of *adapted information* in which the child tries to convey information of some kind to his hearer and *questions*. In both of these categories a distinct relationship not only to age but also to the social background of the home as indicated by paternal occupations can be seen.

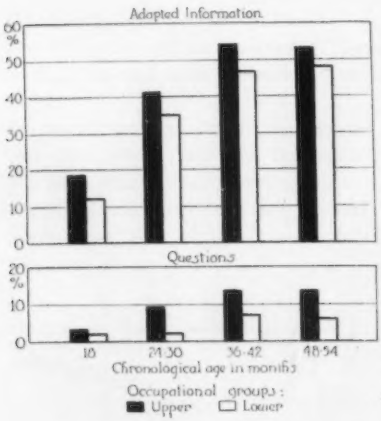

FIG. 7. FUNCTIONAL ANALYSIS BY CA AND PATERNAL OCCUPATION

(Reproduced by permission of the University of Minnesota Press from *Language Development of the Preschool Child* by Dorothea McCarthy.)

Growth in Extent and Range of General Information.—Another aspect of mental development which affords fascinating possibilities of study has to do with the variety and kind of information possessed by children, and the concepts they have formed with regard to the nature and causes of the events that transpire about them. One of the more recent studies on this topic was carried out by Probst, using as subjects 100 Minneapolis children between the ages of five and one-half and six years, equally divided as to sex and selected to constitute a representative sampling of the Minneapolis population. A series of 132 questions was devised, covering such general categories as local points of interest, time and number, current topics and history, literature and music, natural phenomena, occupations and industries, etc. The children were questioned orally and individually, and their responses to the various questions were recorded verbatim. One of the most interesting results of this study is to be found in the number and variety of incorrect responses made to questions on matters with which children are usually assumed to be entirely familiar. For example, a carpenter fixes carpet-sweepers or repairs cars, butter is made from buttermilk, or butterflies make it, plants, seeds or flowers are manufactured in the Ford plant, baking powder is what ladies use on their faces. Sometimes quite elaborate and fanciful explanations are given. The heat in the summertime comes from stoves at the south pole. When the stoves are turned off it grows cold. Coal is made at the north pole by God. Examples of this sort can be multiplied almost indefinitely.

In his studies of children's concepts, Piaget[9] finds that there are definite age stages in the opinions commonly held by children with regard to the natural phenomena which they observe. For example, children under the age of six

or seven years commonly think that a closed room contains no air. Air is outdoors; it can come in when the windows are open but only from the outside. When a hole was made in a rubber ball and the ball deflated in such a way as to produce a current of air against the child's face, the younger children almost unanimously stated that the air which came out the ball had been put into the ball by the man in the store from whom the ball was bought. This air, it was believed, did diffuse itself about the room but remained stationary at a short distance from the ball. When the ball was allowed to inflate itself again the same air that had been in it before and which had been waiting outside, went back into the ball like a dog returning to his kennel. When a current of air was produced by clapping the hands together the younger children were certain that in some way the air must have come into the room from outside. This was the only possible explanation for them since they believed that the room itself contained no air. Children a little older believed that the air came out of the experimenter's hand, in the same way as the breath can be felt coming from the nose and the mouth.

In addition to the qualitative aspects of investigations such as this, and the light they throw upon the developmental stages in children's thinking, the results of information tests may be studied quantitatively in terms of the number of correct answers to the questions asked. Table 1 shows the percentile distributions of the number of correct responses as found by Probst according to the upper and lower halves of the occupational classification previously described and to the sex of the children. At all levels of performance the boys are significantly better informed than the girls, while the difference between social classes is even more marked than the difference between the sexes.

TABLE 1. PERCENTILE DISTRIBUTION FOR THE SCORES EARNED BY 100 KINDERGARTEN CHILDREN ON A GENERAL INFORMATION TEST ACCORDING TO PATERNAL OCCUPATION AND SEX OF CHILDREN

Percentile	Occupational group		Sex	
	Upper half	Lower half	Girls	Boys
10	52.8	36.5	39.5	51.2
20	65.9	45.9	48.5	61.2
30	72.5	54.5	57.0	69.5
40	77.5	59.8	62.3	73.1
50	81.2	63.8	67.0	76.6
60	83.9	69.5	75.7	80.2
70	90.3	75.3	80.9	83.8
80	94.5	79.5	84.5	92.8
90	102.—	84.5	90.8	101.2
95	106.4	88.7	93.9	105.3
100	107	102	107	107

(Reproduced by permission of the Williams & Wilkins Co. from "A General Information Test for Preschool Children" by Catherine Probst, *Child Development*, 1931, 2, p. 88.)

Very similar results have been found for older children. At Stanford University[10] an information test was given to a group of approximately a thousand gifted children with intelligence quotients of 140 or above and also to a control group of unselected children from the public schools. The difference in scores earned on the information test by the two groups was even greater than the difference between their intelligence test scores on the basis of which the gifted children were selected. Sex differences were fairly marked, particularly among the gifted group, and were in the same direction as those found by Probst for kindergarten children in Minneapolis.

The Development of Perception.—As commonly used the term perception covers a wide range of abilities. Thus, there is the perception of form and pattern, the perception of distance, the perception of color, of relative weight, length, position and so on. It is impossible here to do more than give a rough idea of the kinds of investigation that are being carried out in this field.

The popular story of the baby's reaching for the moon has been put to experimental test in a number of laboratories. At the University of Iowa, Updegraff by means of a specially constructed apparatus, compared the ability of nursery school children and college students to judge distance. She found that by the age of four years the children's judgments were almost as correctly made as those of the adult. Apparently the factors which determine the appropriate reaction to distant objects reach their full development very early in life. At Minnesota, Jones studied the comparative ability of children between the ages of three and five years and college students to match lines five and ten centimeters in length on the Galton Bar. She found rapid improvement in matching up to the age of five years, at which age the children were but slightly less accurate than the adults.

A somewhat different type of study has to do with the age changes in the particular aspects of a given situation to which the subjects react. In an

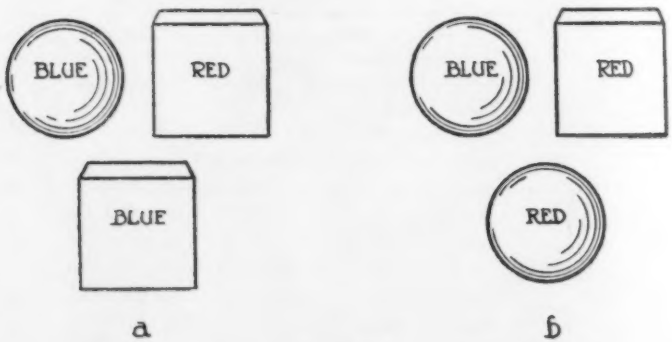

FIG. 8. ILLUSTRATING PLACEMENT OF FORMS BEFORE CHILD

(Reproduced by permission of the Psychological Review Co. from "The Relative Potency of Color and Form Perception at Different Ages" by C. R. Brian and F. L. Goodenough. *Journal Experimental Psychology*, 1929, 12, p. 199.)

experiment carried out by Brian and myself a few years ago, an attempt was made to ascertain whether color or form is more potent in determining the reactions of people in general to simple objects and, furthermore, whether this relative potency tends to change with age. A series of simple geometrical solids and surfaces painted in different colors were used as the material for this experiment. Two objects differing both in form and in color were placed before the subject. A third object resembling one of the first pair of objects in color and the other in form was placed equidistant from each and six inches nearer to the subject. The subject was then told to select that one of the original pair of objects which most nearly resembled the third. The arrangement is shown in Figure 8.

If the subject matches on the basis of color he must ignore form; if he matches on the basis of form he must ignore color. The experiment was continued until each subject had made a total of twelve choices.

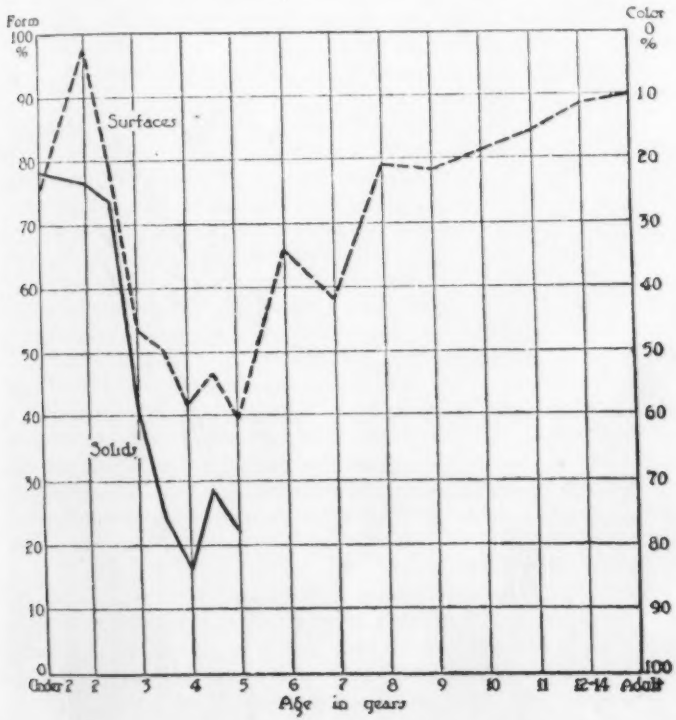

FIG. 9. CHANGES IN THE PERCENTAGE OF FORM VS. COLOR CHOICES WITH AGE

(Reproduced by permission of the Psychological Review Co. from "The Relative Potency of Color and Form Perception at Different Ages" by C. R. Brian and F. L. Goodenough, *Journal Experimental Psychology*, 1929, 12, p. 203.)

A total of 475 subjects ranging in age from fourteen months to adults were used. With the children below six years both solid and surface forms were used. With those above six only the surface forms were used.

Figure 9 shows the age changes in the proportionate number of choices for color and form respectively. It is evident that there is a certain period of life during which color appears to be accorded greater relative significance than at any previous or succeeding age level. This period begins at about the third birthday or slightly before and continues until about the age of six years. The tendency appears to reach a maximum at approximately four and a half years.

The reason for this change is not apparent. A number of hypotheses might be suggested, but experimental verification is in general lacking. It may be thought that the early preference for form is determined by reason of imperfect color perception at the early ages. This hypothesis, however, seems improbable in view of a very carefully controlled experiment by Staples at Minnesota on the color perception of infants and children, which tends to show that by the age of three months infants can at least distinguish between color and gray of the same degree of brightness. By the second half year of life, color perception is very clearly present, though it is not certain whether all colors are perceived with equal clearness.

It is also possible that the general process of concept development is illustrated here. The early interest in form may perhaps be due to the major importance of form in the child's first attempts at organizing and classifying the objects of his environment; the learning of names. Many investigators in the field of language development have shown the existence of a naming stage in the early development of speech. During this period the child's vocabulary consists chiefly of nouns. The later interest in color may be brought about by the fact that after the child has learned the names of most of the important objects in his environment, his interest shifts to the question of making finer distinctions between them. In this process, color is of great importance. The final swing towards form may perhaps be interpreted as the result of gradual organization of the various attributes of a given situation in terms of those factors that experience has shown are most frequently effective in determining appropriateness of response. Although this explanation is largely speculative, it is interesting to note that the early preference for form corresponds to the age period when nouns make up the major percentage of the child's speech, and that the swing toward colors occurs when other parts of speech, particularly adjectives, first become important.

Sleep.—The question of the amount of sleep needed by the average healthy child at various ages is and has been a matter of much discussion. The standards laid down in various books on child care vary greatly from one supposed authority to another; the differences in some cases being as great as three hours at a given age. The problem of determining the optimum amount of sleep is an extremely difficult one and necessarily involves a great deal of subjective judgment. It is, however, possible to determine with relative accuracy about how much time the average child of a given age actually spends in sleep. A number of investigations designed to answer the latter question

have been carried out in various places during the past few years. One of the most interesting and suggestive results of these investigations is the finding that however much authorities may disagree, the children, at least, agree. The averages obtained by different investigators that are based on the actual observation of the amount of time spent in sleep by children usually show not more than a few minutes variation from each other, although the judgments of the experts frequently vary by as much as two or three hours. It is not my

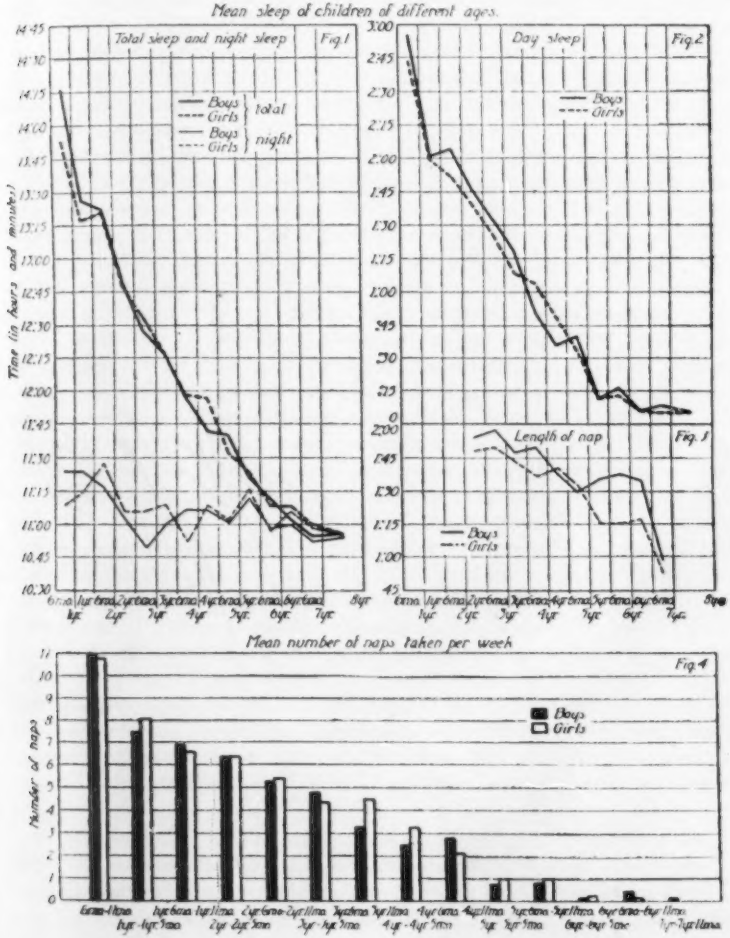

FIG. 10. SLEEP OF YOUNG CHILDREN

(Reproduced by permission of Clark University Press from "The Sleep of Young Children," *Pedagogical Seminary and Journal Genetic Psychology*, 1928, 35, p. 209.)

purpose here to assert whether the children or the experts are right, but we can say confidently that the children are more consistent.

Figure 10 shows the age changes in the total amount of sleep and in the length of night sleep taken by children up to the age of seven years. The data are based upon approximately 1,200 Minnesota children whose mothers kept records of their sleep over a period of one week during the month of October. Records were also kept for a week in each of the three remaining seasons in order to ascertain how much variation there is from season to season in the amount of sleep taken by children.

Figure 10 shows that for children between the age of six months and seven years only slight changes are to be observed in the average length of night sleep. The greater amount of sleep taken by the younger children is due almost entirely to the day nap. As age advances, the frequency of naps falls off rather sharply until by the age of seven practically no children are taking more than an occasional nap. Discontinuance of the nap seems to take place according to an all or none principle. Older children do not nap for shorter periods, but instead the nap tends to be omitted as a whole. The average length of the nap when a nap is taken shows only a small decrease with age.

Although our study does not extend beyond the age of seven years a number of investigations made elsewhere shows that the curve of total sleep continues to decrease with age throughout the period of childhood. At the later ages, however, when the nap has been generally discontinued, night sleep begins to be shortened. The beginning of this trend can be seen in Figure 10. A study by Terman and Hocking[11] which covers the elementary school period agrees very closely with our data in the amount of sleep taken by six- and seven-year old children, after which the night sleep grows steadily less until at the age of thirteen the average child is sleeping about nine and one-half hours at night as compared to over eleven hours at the age of six.

A second type of sleep investigation has to do with the frequency of movement during the night. Studies by H. M. Johnson of the Mellon Institute at Pittsburgh using adults as subjects and by C. R. Garvey of Minnesota upon nursery school children have been made by the use of special beds to which a recording device is attached that registers each movement of the sleeper upon a revolving drum. The results show that children move much more frequently during the night than do adults, that there is a characteristic rhythmic sequence of movement which, in the case of children, appears to be very much alike from one subject to another, while in the case of adults marked individual differences from one person to another in the pattern of nocturnal motility can be observed.

Social Behavior.—An experiment by Charlotte Bühler[12] of Vienna carried out in New York City at Baby Health Clinics has been much quoted. The method employed by Bühler was to place two infants in a crib facing each other and then to observe and classify their behavior. A total of 146 children, all under twelve months of age were used.

Bühler classifies the age changes in the reactions of the infants toward each other somewhat as follows: At about the second or third month the glance

comes to rest on the other child instead of passing over him as over an inanimate object which is the behavior characteristic of younger children. This is accompanied or followed shortly after by sympathetic crying. About the third or fourth month infants begin to smile and make sounds at each other. Then follows a short period of playing together, but each with his own concerns. At about the sixth or seventh month the children try to use each other's persons as play objects. The grasping age, which appears about this time, brings with it various forms of attempted domination that becomes rivalry if the children are near the same age and strength. However, a number of instances in which one child offered playthings to the other were observed early in the second half of the first year. By the age of eleven or twelve months some attempts at definite cooperative play can be observed. Thus by the end of the first year practically all forms of social interaction are present.

Among older children, systematic observations of the social contacts that they form in the course of their play with each other, the size and composition of spontaneous play groups and the kinds of games most frequently played at different ages have all yielded interesting and suggestive information on the development of social behavior. In a study by Parten[13] in which nursery school children were observed daily for short periods during their free-play hour, and the nature of the social behavior displayed at these times was noted, it was found that definite age trends can be observed in the social reactions of children from two to four years. The group play of two-year olds is in general much less socialized in nature than that of children of three or four. Among two-year olds the group formation seems to be largely a matter of chance. They play together, not so much because of any apparent desire for social relations, but rather because a number of them happen to be interested in a common activity which of necessity brings them together. They play beside each other rather than with each other. There is little conversation and each child carries on his own work as a unit, paying little attention to what the other children are doing. A little later the social influence becomes more manifest. Although the children still engage in individual play, there is clear evidence of the modification of behavior by social factors. The children imitate each other's activities, there is borrowing and lending of material, and suggestions made by one child are carried out by another. Here the beginnings of leadership are observed. The leadership is, however, of a relatively simple fashion as is also the group organization. There is little or no coordination of activity toward a common goal; each child plays a part which is essentially the same as that of every other child. Formally organized cooperative activity is not often seen before the age of four years. In this stage of social organization the children definitely coordinate their activities into an organized whole in which each member has his own individual part. This is seen in playing house and in the more elaborate forms of playing train or school. Such games as these demand a father, a mother, a conductor, an engineer, brakeman, teacher, pupils, and so on. Here the part of the leader is more difficult and more important. Even among the four-year olds one can note evidences of some attempts on the part of the leader to assign rôles in accordance with individual differences. An

amusing instance of this sort was seen in our nursery school when a well meaning but unusually clumsy child attempted to take part in a game of "house" which was being carried on by a number of the children. After several rather insecurely constructed pieces of furniture had been inadvertently ruined, the four-year old "father" of the family announced in tones of authority, "Now, Jimmy, I think you'd better go outside and be the dog." The suggestion was made in all good faith and was so received. Jimmy retreated to the more open spaces outside the playhouse and proceeded to act the part of the perfect watch dog.

Behavior Difficulties.—During recent years widespread interest has been aroused in questions of so-called "behavior problems" in children and in procedures designed to ameliorate these problems or prevent their occurrence. Extensive claims have been made as to the reduction in juvenile delinquency, adult crime, and frequency of mental disease that might be brought about by the general adoption of certain preventive programs. While I do not wish to minimize the enormous importance of the problems involved, nor the desirability of exerting every possible effort for the correction of individual cases, we should not blind ourselves to the fact that the matter is extraordinarily complex, while our knowledge of the fundamental factors involved is extremely limited. After practically every sensational crime of the present day we find newspapers quoting the statements of so-called experts to the effect that had this person been given the benefit of expert advice and treatment during childhood or youth, his subsequent behavior might have been foreseen or prevented. Assertions such as this are harmful in that they give to the general public a very erroneous concept of the true extent of our present knowledge with regard to causative factors in behavior. Here as elsewhere real scientific advance is contingent upon carefully conducted investigation with results unbiased by wishful thinking. A very promising investigation along this line is in progress at Toronto under the direction of Blatz.[14] Through the cooperation of the public schools, records are kept of all misdemeanors, even of a relatively trivial nature, shown by the children in a large public school. Results are being studied to show the age changes in the frequency and kind of offences, and the consistency of the behavior of the same children from year to year. The latter aspect of the study is particularly important, since it should throw much light upon the extent to which later behavior can be predicted from early behavior. Although only preliminary reports on this investigation have appeared as yet, some of the facts brought out are very significant. For example Blatz shows that the significance that can fairly be attached to a given non-social act varies greatly with the age and to some extent with the sex of the child. At the age of nine years, stealing, particularly among boys, occurs in so large a percentage of the school population that it may fairly be regarded as a normal behavior trait unless it occurs rather frequently. Occasional pilferings need not cause too great concern. As age advances, however, the proportion of children who steal drops off very rapidly. By the age of twelve or thirteen much more significance should be attached to stealing than at the age of nine.

At the University of Minnesota Institute of Child Welfare we have from the beginning made a practice of rating all children who are brought in for mental tests according to their emotional reactions during the tests. Three factors have been considered, shyness, negativism, and distractibility. Marked individual differences are shown at all ages. In some cases these differences seem to be in part related to certain objective factors in the home situation. I shall present only one such finding; the relationship of negativism as displayed in the test situation to sex and to the occupational class of the parents. Figure 11 shows the results from 875 examinations of children between the ages of eighteen and fifty-four months.

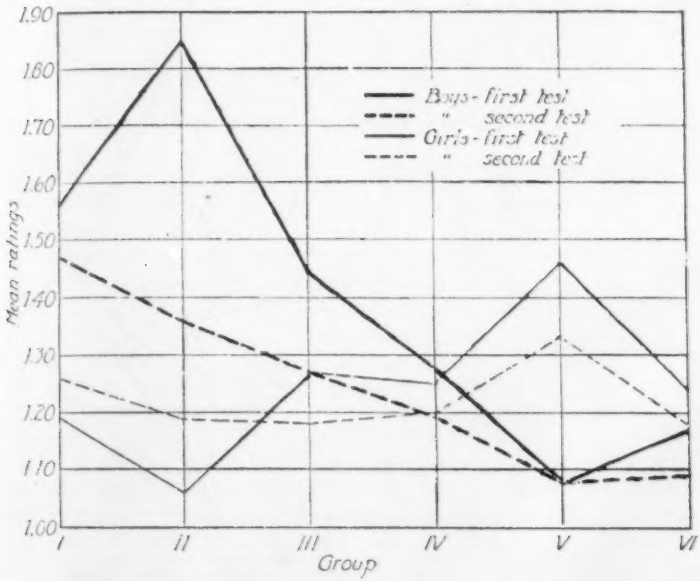

FIG. 11. MEAN RATINGS ON NEGATIVISM BY SEX AND PATERNAL OCCUPATION

(Reproduced by permission of the University of Minnesota Press from *The Kuhlmann-Binet Tests for Children of Preschool Age* by F. L. Goodenough.)

Figure 11 shows that upon the whole, negativism in the test situation is displayed by the boys to a somewhat greater extent than by the girls. However, when the data are considered with reference to the occupational classification of the fathers, the gross sex difference seems to be secondary to a social difference that operates unequally for the two sexes. Among the boys the greatest display of negativism is found in the upper occupational classes. For the girls the findings are very different. There is no very consistent difference between the social classes in respect to this trait, though there is some indication of a trend in the opposite direction than that which was found for the boys,

that is, more negativism among the children whose fathers belong to the lower occupational groups. However, the differences are within the limits of chance. Taking the figures at their face value it would appear that in occupational groups I, II and III the boys show more negativism than the girls, in group IV no real sex difference is apparent, while in groups V and VI the girls are somewhat more negativistic than the boys. In a group of 561 cases ranging in age from six months to five years and selected almost entirely from the lower occupational groups, Levy and Tulchin[15] found girls to be more resistant to the test-situation than boys at all ages except at thirty months. For their cases the greatest negativism was shown by the boys at eighteen months and by the girls at thirty months.

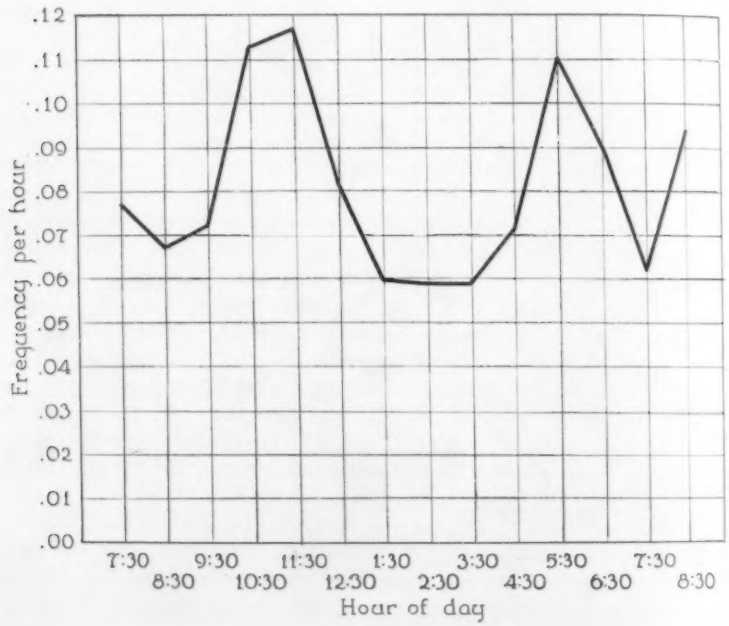

FIG. 12. DIURNAL VARIATIONS IN FREQUENCY OF OUTBURSTS OF ANGER AMONG YOUNG CHILDREN

(Reproduced by permission of the University of Minnesota Press from *Anger in Young Children* by F. L. Goodenough.)

I shall mention only one other study. This investigation has special interest because it is illustrative of the type of contribution that can be made by intelligent and cooperative parents. We are fortunate in having many parents of this class in the Twin Cities. A number of mothers kept records of every outburst of anger shown by their children during a period of from one to four

months. In addition to a formal account of the outburst itself, the factors which led up to it, and the methods that were used in an attempt to control it, records were also kept of a number of additional factors that might perhaps be expected to have some relation to the child's state of irritability. Figure 12 might be called a "temperature chart," since it shows the distribution of "temper tantrums" of greater or less extent over the several hours of the child's day. The data are based upon records of 1,878 actual outbursts shown by forty-five children. The graph shows the ratio of the total number of outbursts to the number of times that each child was under observation and awake during the hour indicated.

The first peak in the curve comes before breakfast. After the breakfast hour the frequency remains low until about 9.30 in the morning when the curve rises rapidly until the hour of the noon meal. Thereafter it falls abruptly and again remains at a low point of frequency until the latter part of the afternoon when we have a second rise to a high point between five and six. Thereafter the curve falls, but rises again shortly and continues to rise until bedtime. In a study of college women, Gates found essentially the same relationship between irritability and the meal hour that is shown in our study. The popular opinion that a full stomach makes for contentment and placidity seems experimentally verified in these studies.

In these rather brief summaries I have attempted to give something of a bird's-eye view of the types of investigation by means of which we are endeavoring to trace the development of human behavior from childhood to maturity. Even from this very incomplete summary it should be evident that the problem is too complex and the determining factors too numerous to be covered by any single formula that the present state of our knowledge permits us to develop, nor can we as yet point to any one rule by which individual development can be guided to a predetermined end. A recognition of the many sources of error to which even carefully collected data are subject should warn against the formation of hasty conclusions or the making of dogmatic assertions from insufficient evidence. Nevertheless, a begining has been made. From the mass of data, sometimes conflicting and often confusing, that constitutes the present basis for the beginning science of human development, one fact of tremendous importance stands out.

In Function as Well as in Structure, Human Development Follows an Orderly Course.—This course is determined by laws as definite and as inexorable as those of the physical sciences, or as those governing the organisms below the human level. We cannot change these laws, but we can utilize them if we know their nature. The prediction and control of human behavior is a problem that, for sheer importance, may well be said to be without a peer. Prediction and control, however, is contingent upon a sound knowledge of the fundamental principles involved. It cannot be brought about through dogmatic assertions of unsubstantiated opinion, by publicity campaigns or by wishful thinking. We can hope for advance only through the application of principles that have a solid foundation in scientific fact. Perhaps it is not too much to hope for a time when the welfare of children may be thought worthy of as

careful scientific study as is now given to improving the breeds of cattle and poultry or to ascertaining what kind of soil is best suited to the raising of wheat and corn.

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ENTITIES AND ORGANIZATION IN CURRENT BIOLOGICAL THEORY*

F. S. C. NORTHROP

The present paper is part of the fifth chapter of a book on the fundamental conception of science. The reader will find occasional references to ideas which are fully treated only in earlier chapters. It has seemed wise to leave these references as they stand, since the paper has its own thesis which is in no way distorted by their presence, and living creatures are so essentially conditioned by the physico-chemical, and the most general scientific and philosophical principles of nature as a whole that any correct account of their more strictly biological characteristics must include the intrusion of such extra-biological factors.

However, there is one fundamental thesis expounded in the book and appearing in this paper, which is so unconventional that a word concerning its significance for biological theory is necessary.

Living organisms exhibit among other properties an atomic or physico-chemical constitution, and form or structure. These two factors appear in our title as entities and organization. Historically science has never succeeded in finding a theory of first principles which will do justice to both of these attributes. Always it has had to choose between two theories which provided meaning for one at the expense of the other. This is the crux of the issue between mechanism and teleology and between atomism and organicism. In history it appears in the conflict between the Aristotelian and the modern conception of science. Aristotle, approaching living creatures through description and classification by way of natural history was impressed by their form and organization, and hence introduced formal as well as material causes. The result, as he saw, and accepted in his metaphysics, was the rejection of physical atomic categories. Matter became, along with form, the mere attribute of a dynamic teleological activity. Modern science, on the other hand, approaching the living creature through the experimental investigations of Harvey, Lavoisier, Liebig, Wöhler, and others found it necessary to accept the physico-chemical theory of both living and non-living systems. The result, as Claude Bernard saw and as J. S. Haldane has emphasized more recently, is the failure to account for organization. Ancient biology provided for form with a resultant rigid fixity of types at the expense of entities and the fluidity of species; modern biological theory provides for the non-fixity of types and the presence of physico-chemical and genetical entities at the expense of organization. The significance of the macroscopic atomic theory which is presupposed at certain points in the following pages, can be appreciated only if this dilemma is kept in mind. It provides science for the first time with a philosophical conception of nature, stated completely in physical terms, which makes it possible to regard the

* A paper read before the Yale Chapter of Sigma Xi, the major portion of which is reprinted with the kind permission of The Macmillan Company from the author's book, *Science and First Principles*, New York, 1931.

physico-chemical and electro-dynamic elements of modern science as primary and at the same time provide meaning for an irreducible organic principle in nature. A choice between physico-chemical categories with the attendant denial of any ultimate organic principle, and organicism with its reduction of the physico-chemical to a mere abstraction is no longer necessary. In accord with the present tendency of physics to emphasize macroscopic field conditions as well as microscopic entities, one conceives of nature as a whole and each living and non-living system organically related because of its essential connection with that whole, as an equilibrium between, and as compounded out of, internal microscopic physico-chemical constituents and a single physical macroscopic factor. In short, nature as a whole and each local component system is grounded in the dimension of the large as well as the dimension of the small.

It is one task of the empirical scientist to determine how these two basic physical microscopic and macroscopic factors compound to produce the systems which constitute the subject-matter of his special science. The account which follows* aims to determine whether living creatures as observed by the experimental biologist evidence the presence of these two general factors and, if so, precisely how and where they appear.

This undertaking falls naturally into three parts: the raw materials of life,[1] the organization of those materials, and the mechanics of the evolutionary process which has made them what they are in man.

HEREDITY AND THE THEORY OF THE GENE

The science of the raw materials of life is genetics. Its theme is heredity.

The significance of heredity is self-evident. It appears the moment one considers the relation between the characteristics of parents and their offspring. An unexpected principle reveals itself when this relationship is studied carefully and experimentally. It appears that the observed characteristics of living things have an atomic and permutative character as they present themselves in connected generations. A single example will indicate this. Take such a simple case as the crossing of red and white flowers. The product is pink. But in succeeding generations the red and white can be regained. The situation is quite analogous to the one which drove chemists to the discovery of the atomic theory of matter. Lavoisier heated the semi-liquid silvery mercury with oxygen and gained a powder of an entirely different color, which upon being heated again with carbon gave back the original semi-liquid silvery mercury without any loss in weight. Similarly organic traits have this atomic and permutative character. We can understand, therefore, why the biologists, and particularly the geneticists, have been led to the doctrine of hereditary elements, called genes.[2]

Moreover these atomic characters seem to relate themselves according to the permutative rules of chance combination. The laws of Mendelian heredity express this fact. Also the genes or hereditary elements located in the chromosomes of every cell are physico-chemical substances. The experiments of Muller,[3] in which they and through them the subsequent progeny are affected

* *Science and First Principles*, pp. 207-230, The Macmillan Company, New York, 1931.

by x-rays, establishes this point. Hence they have a complex physico-chemical nature. In other words, although they are atomic from a genetic point of view when one ignores their changes, they are complex from the physico-chemical point of view. Because of this complex constitution there is nothing to prevent them from undergoing an addition to, or reorganization in, their structure, such as Muller has produced. Such a modification in structure the geneticist calls a mutation. Since Muller's experiments, in which such a mutation is produced by x-rays, induce a modification in observable specific parts of the offspring, a definite connection seems to be established between the inherited characteristics of living organisms and the organization of certain complex physico-chemical substances located in the chromosomes of the germ cells. It seems to be by a splitting and combining of these complex substances and the chromosomes in which they are located that the physiological assets and liabilities which we take over from our two parents at the beginning of life are in part at least determined.[4]

Moreover, contemporary biologists are convinced that reorganizations of these complex substances are at the basis of the mechanics of the evolution of new forms of life. There can be little doubt but that more of a load has been placed upon the genes than they are able to carry. We shall find that such an explanation, while partially correct, is entirely too simple and easy an account, and ignores too many other known factors to be regarded as the whole truth. On the other hand, those who emphasize the positive causal influence of external factors in evolution must never forget one fact: It is not enough for the environment to produce a new organization in living matter; that new organization must be inherited before a new form can establish itself, and inheritance is tied up with combinations, mutations, and reorganizations in these complex substances in the chromosomes. Also, regardless of the degree of seriousness with which one takes the theory of the gene, one fact independent of all entities, whether postulated or real, remains; namely, certain hereditary traits of human beings, in common with all other forms of life, reveal in their relations that an internal, pluralistic, permutative atomic principle is one foundation of human nature. The manner in which human traits shuffle themselves from generation to generation, entering into and passing out of all possible permutations, permits no escape from this conclusion. The pluralistic microscopic principle is at the basis of human as well as inanimate nature.

Nor does this surprise us. It is exactly what our first principles of science require. The macroscopic atomic theory necessitates that a kinetic microscopic principle must exhibit itself in the raw constituent materials of any complex natural system. Moreover, our analysis* of the foundations of organic stability points toward the same conclusion. Recall again the delicately but dependably balanced physico-chemical system which our analysis* of Henderson's nomographic picture[9'] of a typical protoplasmic system revealed. A living thing is a temporary dynamic physico-chemical equilibrium between external and internal elements, which is constituted of such peculiar complex chemical compounds, by the chance variations arising from the kinetic microscopic principle

* *Loc. cit.*, Ch. IV.

and the automatic natural selection due in part indirectly to the macroscopic atom, that the active chemical processes involved in life either run in a cycle to repeat themselves and preserve certain constancies through the system as a whole, or automatically initiate compensatory reactions for any destructive influence which the normal circumstances of life introduce. Obviously, the kinetic microscopic principle exhibits itself in the dynamic chemical properties of this system. But it is also present in a more specific sense. The stability of the system and the type of reaction that it gives to a certain change in one of its components is determined not merely by the dynamic equilibrium which the macroscopic factor* imposes but also by the presence of certain complex and unusual physico-chemical compounds. With these key substances present, the normal materials of the inorganic environment, congested eternally by the macroscopic factor*, must interact to produce those enlarging systems which we call growing living organisms; without them a flux of chemical composition and decomposition would cover the face of the earth. Moreover, since these compounds are essential for the existence of life it follows that they must be transmitted to succeeding generations, if a given form is to preserve its type. Furthermore, since organisms result automatically from the normal interaction of these key compounds with the environment, it is only necessary to transmit them to succeeding generations to preserve a given form of life. We can understand, therefore, why the science of genetics has found heredity to be centered in certain complex physico-chemical substances located in the germ cells.

Since these compounds have their basis in moving physical particles which tend to give rise to new permutations, we can appreciate why spontaneous, internally conditioned mutations seem to be one key to the mechanics of evolution, and why the observable hereditary materials of man's nature exhibit an atomic and permutative character in their relations.

Much has been written by defenders of a monistic philosophy concerning the failure of the physical theory of nature to do justice to the nature of man. Nevertheless the plain fact is that the character and behavior of the observable raw materials with which we begin life are unintelligible unless nature is a physical kinetic atomic system. More may be involved, but this at least is certain. The raw materials of human nature find their basis in the microscopic atomic principle of our theory.

ORGANIZATION

But in addition to the raw materials of living creatures there is their organization or form. Certain experiments in embryology indicate that the source of this is not to be found in the hereditary materials alone. At an early stage in the development of the fertilized egg of certain organisms, Spemann[6] and O. Mangold[7] have transplanted groups of cells which normally produce certain tissues and organs of the animal. They find in certain instances that the fate of the cells is determined, not by their internal constitution, but by their relation to other cells of the organism. For example, the portion

* *Loc. cit.*, Ch. II.

which normally develops into the brain of a certain organism may be transplanted to another portion of the animal, where it develops into the quite different organs of that region. Evidently form, as well as the hereditary material, determines the character of a living thing.

What is the source of this form? Another experimental discovery made by Spemann throws some light upon this question.[5] He found a semi-circular area known as the upper lip of the blastopore of the developing embryo which behaves quite differently when transplanted. Instead of changing its gross character and fate, it retains its normal character and becomes a center around which neighboring material arranges itself. When only part of this material is transplanted the remainder of the system arranges itself relatively to both parts. The orientation relatively to the normal position of this material Spemann terms the primary embryo; the orientation relatively to the transplanted material he calls the secondary embryo. Two points of significance for subsequent considerations are to be noted. In the first place, the secondary embryo need not have the same orientation as the primary embryo. And secondly, this region of the embryo which does not change its fate when transplanted is near, but is not identical with, the material that gives rise to the nervous system. Although the nervous system does not arise out of this dominating material, it arises in the immediate neighborhood of this material.

This portion of the developing embryo which does not change its fate when transplanted Spemann calls the organizer.[5] Is not this title somewhat misleading? The fact which it denotes is merely this: Certain portions of the embryo change their fate when transplanted, others do not. But to use the term organizer to denote the latter half of this fact is to suggest that the material which does not change its fate is the active source of organization. This is quite a different thing, and something concerning which, so far as one can see, his experimental evidence says absolutely nothing. One does not regard a pile in the moving water of a lake as the active cause of the wave formation which exists around it, even though the wave formation comes and goes with a shift in the position of the pile from one side of the lake to the other. The organizer may have no more significant rôle, or as is even more likely, its significant activity may center in active chemical materials, or in integrative factors much more fundamental and far-reaching than it.

In thinking about the developing embryo it is well to remember that the diverse organs which finally arise in the more complex living systems are but crystallizations of certain original properties of protoplasm. Thus the circulatory system, with its heart and associated network of arteries and veins and capillaries, is but an expression of the flowing fluid character of original semi-liquid protoplasm. Similarly the metabolic system has arisen out of the chemical and energy transformations within this fluid material. Now, the specific organic structure which integrates the other processes and organs of the body to produce the unitary form and organization of the system as a whole is the nervous system. Hence a consideration of its essential characteristics and origin should throw light on the problem of form.

It has three major characteristics. In the first place, as we have indicated, it integrates[8] the organism as a whole. Thus we may regard it as a crystallization of the form of original protoplasm. Secondly, it is the center of sensitivity. This attribute of the nervous system is but an expression of that most general property of original protoplasm known as irritability. From this the third important attribute of the nervous system arises. It records within the internal organization of the organism the relations of the living creature to the rest of nature. In short, it is an equilibrium between the many raw hereditary materials within and the external factors without. This property is present in living matter long before specific neural organs arise. For example, the single-celled amoeba responds to objects within its immediate environment with which it is not in direct visible physical contact. Evidently the specific character of the environment records itself, at least in part, in the internal organization of each living thing.

One would judge, considering the emphasis which they put upon genetics, that most contemporary biologists would place the source of the nervous system completely in the genes. But this does not seem to be justified. One of the essential functions of the nervous system is its rôle as an integrative factor. Integration calls for a unitary principle, whereas the genes represent a pluralistic principle. Moreover, the earlier experiments of Spemann suggests that form does not depend upon the internal bodily materials alone. It is something into which they enter, but not something which they alone produce. Also, the manner in which the nervous system records external relations and objects points quite unequivocally toward an external organic factor as well as toward internal entities as its source.

Furthermore, the organic character of the inorganic universe and of living things has been so firmly established by recent physics and physiological chemistry that one must be very suspicious of all theories of biological organization which would locate its source wholly in internal entities, whether they be entelechies, or genes, or organizers. At a time when certain physicists are threatening to throw all entities out of inorganic nature, and leave nothing but mathematical equations and formal relatedness, it comes with something of a shock to find so many contemporary experimental zoologists locating the form of that most organic of systems, the living organism, in nothing but internal entities.

One finds it difficult to escape the impression that contemporary biology, except for the work of the physiological chemists, is in much the same state as were physics and chemistry a decade ago, when everything was located in electrons and protons, and the wave theory and field conditions which supplement these microscopic particles had not been discovered.

Yet there is no reason why biological philosophy should be in such a state. Enough evidence is at hand to correct the one-sided over-emphasis of the gene theory. The only difficulty is that one must cultivate the philosophical attitude of mind in order to know it. But this is inevitable. The chemist is concerned with the properties of gross matter, the physicist with matter and motion, the astronomer with stellar bodies, the student of thermodynamics with energy

and its transformations; but the living organism is all these factors merged into a grand synthesis. Moreover, the essence of life centers in the cosmic forces which produce the synthesis as well as in the local constituent materials themselves. Now the science of the synthesis of the sciences is philosophy. Hence, to understand life without looking at one's local technical experimental evidence from the philosophical point of view is impossible.

This does not mean that every experimental or descriptive biologist should close his laboratory and study professional philosophy; it does mean, however, that the present approach to living things through intensive analysis must be supplemented by the construction of a general accurate picture of the living organism in its actual physical, geological, chemical, astronomical, and thermodynamical connection with the rest of nature. It is because Henderson's nomogram[9'] forms the starting point for such a construction that it is important. There is even more need for the theoretical biologist than for the theoretical physicist.

Otherwise the senses are always misleading the experimental worker. Unless one is continually correcting and supplementing observation with a correct conception of the general physico-chemical nature of life as a whole, which reveals it to be a complex heterogeneous physico-chemical equilibrium rooted as unequivocally in the physical and dynamical foundations of the environment as in internal private genetical materials, the apparently solid character of living things causes one to regard them as a purely local entity. Then the notion arises that life is to be understood solely in terms of what is contained in the gross local body itself. Once this false assumption takes hold of the mind, the postulation of an endless series of entities both physical and vital is inevitable, and one's biological theory becomes increasingly false to the extent that one's experimental evidence is increasingly sound.

Because certain local observable inherited traits of man reveal an internal pluralistic atomic principle to be at the basis of his nature, one must not conclude that all his characteristics have such a basis. Nor must one conclude because certain transplanted materials of the developing embryo are unable to change their characteristics when transplanted, that they are the active cause of organization. Before an adequate theory can be expected we must consider the general characteristics of the living organism in the light of the first principle of science which condition them.

This brings us back to the general physico-chemical properties of life which were revealed in L. J. Henderson's nomogram of the blood,[9'] and to the theory of the first principles of science which our analysis of inorganic nature has suggested.* We must bring our conception of the nature of man into harmony with these factors.

An analysis of certain strategic conceptions in relativity and atomic physics and general physiology has forced us to the discovery of a new theory of the first principles of science.* Nature is constituted not merely of the electrons of traditional physical theory, but also of one large spherical physical macroscopic atom which surrounds and congests them. The congestion arises solely

* *Loc. cit.*, Chs. II, III, and IV.

from the fact that the diameter of the macroscopic atom is finite in length and so short relatively to the very large finite numbers of microscopic atoms which it contains that they are crowded together to form an equilibrium. This equilibrium between the outward pressure of the microscopic particles and the inward pressure of the macroscopic atom resulting merely from the finite size is compound, or molar, nature. It is to be noted that the macroscopic atom produces its effect by no mysterious or changing activity, but by keeping its properties fixed and merely being what it is. To use Aristotle's expression with a quite different meaning, it is an "unmoved mover." The fixed physical spherical form of this macroscopic atom necessitates that the equilibrium which is molar nature is given a form. Tradition has termed this macroscopic form the order of nature.[9] Moreover this equilibrium between the microscopic and macroscopic must have a dual character. The many enclosed moving microscopic atoms constitute an arithmetical, pluralistic, internal, and kinetic principle, and hence tend to produce many different changing systems; the one static, enclosing, spherical, macroscopic atom represents an externally imposed geometrical, unifying, and eternal principle, and hence tends to produce one static ordered system. Thus it does not surprise us that stellar nature is more static than biological nature, or that nature as a whole is one static and more eternal order of many local temporary organisms. This must be the case if a changeless, perfectly formed, encircling, geometrical one, and a contained, moving, arithmetical many are in polar opposition.

Everywhere we have found this opposition and synthesis of polar principles to apply. Space-time is a union of general macroscopic metrical uniformity and constancy, and local microscopic heterogeneity and variability; atomic physics and optics exhibit a union of a continuous monistic wave medium with its macroscopic boundary conditions, and a discontinuous and contingent grouping of particles; and the most general protoplasmic system, when viewed from the physico-chemical point of view, appears as an organized equilibrium of the atomic materials of the whole of nature, including those without as well as those within the epidermis of its body. In short, everywhere in inorganic nature we find externally conditioned organization and continuous field conditions merged with local, internally conditioned, complex materials and the discontinuity which they entail. Out of nature has come the living organism and from its first comparatively simple and homogeneous form has come man. It would be strange indeed if this opposition and synthesis of polar principles did not apply to him also.

The presence of the microscopic principle has already been discovered in the dynamic chemical attributes of life, in its dependence upon very complex key compounds for its stability and evolution, and in the atomic and permutative character of inherited characteristics.

But our theory of first principles has other consequences. In addition to the kinetic microscopic principle there is the encircling macroscopic atom. Its spherical geometrical character adds a formal factor at the basis of natural phenomena, and what is more important still, the embodiment of this form in a physical atom insures that its presence is effective; it has at its disposal the

physical forces which are necessary to change the direction of motion of the moving microscopic particles. This form must exhibit itself immediately in the general order of nature, and because of the congesting factor this order of nature must exhibit itself in every local system. Upon the raw materials of life there must be imposed organization. We are not surprised that Spemann found the fate of certain cells in the developing embryo to depend upon their relation to other cells of this system, or that such competent students of life as Aristotle, Claude Bernard, and J. S. Haldane discovered living organisms to be physical systems whose organization is not completely intelligible in terms of their internal constituent materials alone. There is the one organic macroscopic order imposed from without as well as the pluralistic microscopic permutative principle operating from within.

But if the living organism is the sensitive physico-chemical system which Henderson's nomogram has revealed it to be, and if its organization is conditioned by the macroscopic atom operating indirectly through the order of nature from without, it follows that there must be an equilibrium and order between any organism and other organisms and the rest of nature, as well as within it. In fact, the local organization of a plant or animal can have no meaning apart from the one wider order of nature as a whole. L. J. Henderson has found this to be the case,[10] for he has discovered a most intimate and essential relation to exist between the properties of living organisms and the most extensive and deep-rooted properties of the environment. If this be so, the general macroscopic relations which join an organism to the rest of nature, and the specific local relative relations which join it to the objects of its immediate environment must be to some extent internal to it, and must exhibit themselves in the form and specific internal physiology and anatomy of the organism itself. Such externally conditioned internal organization exists in living things. In the amoeba it appears in a capacity to sense the presence of objects with which it is not in direct physical contact, in man it exhibits itself as a definite set of organs known as the nervous system.

It appears that one has but to carry the polar principle of the macroscopic atomic theory to its consequences in such a delicately and sensitively balanced physico-chemical system as Henderson's work has revealed living matter to be, to discover that peculiar merging of raw hereditary materials with an externally conditioned form which is the physiological nature of man. It appears also that the physico-chemical equilibrium which is man is dual in character. There is the balance between internal and external factors revealed in Henderson's nomogram, and there is the equilibrium, between this balance and other organic and inorganic systems, which is the nervous system and its externally and internally grounded internal organization and control. It is because of its localization in the nervous system, which is grounded as much in nature as in man, that man's consciousness is centered as much, and usually more, on nature as on himself.

The importance of the nervous system is such that we must examine its origin and development more in detail. This brings us to the very important work of the American physiologist C. M. Child.[11] His experiments show that

external factors, because of the greater effect which they have on certain portion of the organism than others, lay down regional differences in the system, and tend to orient the formal arrangement of the internal material relatively to these differences. Let a ray of light fall upon a simple protoplasmic system. It affects one portion of the system more than others. Naturally this makes a region of higher activity in that part. This sensitivity gradually works out through the system growing weaker and weaker as it spreads and proceeds. Thus different levels of activity are created. This series of regional differences Child calls a physiological gradient.

He has been inclined to identify these differences with different rates of metabolic activity. Several considerations suggest that this may need amendment. It would seem as if metabolic activity should depend more on internal chemical materials and the localization of especially active compounds. Also according to Child the gradient is the incipient nervous system. Now the nervous system is like a telephone system rather than a high tension power transmission system. The energy of the body is not stored in the brain and then sent out along the nerves to the organs where it is needed. Instead it is located throughout the body and merely set off by very small amounts of energy sent through the nerves. Hence one would not expect all the energy of the body to be lined in a series of decreasing quantity as one proceeds down the gradient. Furthermore, our theory of first principle suggests that the effect of the external factor is to introduce congestion so that organization is inevitable and to impose formal differences. To be sure, form can only be present if it is embodied in physical factors, as Child has correctly noted. But the physical differences necessary to embody a formal factor can be conditioned by a differential distribution of but a portion of the energy of the body along the gradient, without assigning all the energy of the body to such a distribution. However, this is a minor point. In any event, the essential point in Child's theory remains true. External factors condition regional differences of a physical character in living things and these at least contribute to the determination of the symmetry and form of the body.

Child's work also suggests that these gradients are independent of the specific nature of the external stimulus, and that they arise only in relation to external factors. There seems to be no reason why this should not be the case, even if they orient themselves relatively to the materials which Spemann calls organizers.[12] When one places the fact of the external origin of the gradient in conjunction with the additional evidence which suggests that it determines the axial form of the body, it appears that the available experimental findings support our theory of the form of living things at the crucial points in our doctrine.

This theory is that the specific form of a living creature is to be defined completely neither in terms of internal entities such as genes, or entelechies, or organizers, nor in terms of external environmental influences alone, but that it is the product of the merging of an internal kinetic pluralistic principle and an externally imposed single formal principle. The evidence for the pluralistic principle is present in the theory of genes, in the varying potentialities of the

parts of the embryo when transplanted, as discovered by Spemann and in the physico-chemical constitution of living organisms. The externally imposed unifying formal factor exhibits itself in Child's theory of the physiological gradient.

Of course Child's particular formulation of the manner in which the essential observable internal structure of an organism is determined in part by its environment pole is not essential to our theory. All that our theory prescribes is that the living thing is a physico-chemical system which includes the rest of nature, in part, in its very constitution, and is so intimately and essentially related to other similar organic and inorganic systems by the congestion introduced indirectly through the order of nature by the macroscopic atom that the character of the environment must register itself in the specific internal and more local constitution of the local organism. We have chosen Child's theory because it is the only one in experimental zoology with any respectable amount of evidence behind it, that gives concrete and specific expression to this necessary fact. That his theory expresses the precise manner in which the character of the environment is registered in the observable local organization of the organism is a contention which may be open for debate, but that the kind of determination of organic characteristics for which it stands exists is something which no one can doubt, so far as one can see, unless he rejects all that physiological chemistry teaches us concerning the sensitive character and far-reaching environmental foundations of those physico-chemical systems which we call living organisms.

If this be admitted, we are prepared to summarize the steps which connect the specific organization of living things with the macroscopic atom, which is the ultimate unifying organizing principle in nature. Child's work indicates that the specific symmetry and form of living things is determined in part at least by the physiological gradient and that this gradient never arises except in relation to external factors. This places the one source of organization unequivocally in the order of nature, and calls for some source of that order. Our analysis of the spatial structure of this order forced us to locate it in the macroscopic atom.* Thus there appears to be a very definite and concrete sense in which the macroscopic atom operates through the order of nature to indirectly condition the specific organization of living things.

Two other properties of the gradient must be noted. In the first place, the top of the gradient dominates the lower regions, and hence, if it is the only gradient, the other systems and processes of the organism. Secondly, Child has pointed out that in an axial type of organism such as man the controlling region of the nervous system develops at the dominant end of the major physiological gradient. In general, the nervous system first appears as definite localized structure at or near the anterior end of the major gradient when the primary germ layers of the embryo have become differentiated and before other definite organs and tissues appear.[11] Spemann's organizer may be an expression of this, as Child has suggested.[12] Furthermore, experiments reveal that the structure of the nervous system and the direction of its growth is

* *Loc. cit.*, Ch. II.

associated with the physiological gradient, and that the dominant portion of the central nervous system is located at or near the upper dominant end of the gradient. In man this dominant portion of the nervous system is the cortex of the brain. Thus in terms of the action of external factors upon the raw hereditary materials we can understand why man is an organized physico-chemical system with a nervous system dominated and coordinated by the cortex of his brain.

Certainly if such a system were conscious, its consciousness would be located extensively in nature as well as relatively to this particular body, since the nervous system is an equilibrium between the raw protoplasmic materials within and external nature. Furthermore, the body itself is really an equilibrium involving the whole of nature. Thus, knowledge must have both an absolute and a relative character, absolute in so far as man and his nervous system have their basis in the whole of nature which is common to all local systems and standpoints; relative, to the extent that the purely local and atomic permutations record themselves in his neural constitution. Only by understanding the relation between neural organization and the general physico-chemical organization of man and nature[13] can one hope to understand knowledge.

A full understanding of the physiological nature of man is not possible without a consideration of the evolution and origin of new and more complicated forms of life. We have suggested how the nervous system may have originated to determine a given form of life. How do new forms arise?

THE MECHANICS OF EVOLUTION

The prevalent answer to this question is in terms of a philosophy called emergent evolution. It appears to provide a most plausible solution of the difficulty. Unfortunately it possesses two fatal weaknesses. In the first place, its plausibility is only apparent. We are simply told that new forms of life arise because they emerge. Man asks for a specific solution to a complex problem and he is given a verbal sedative.[14] But emergent evolution has a more fatal weakness. It cannot be true. For it rests on the assumption that time is a primary concept. Relativity physics informs us that this is not the case. Time is relative and must be defined in terms of matter and motion.[8] We must look elsewhere for a philosophy of evolution.

A more specific answer is given by the geneticists in terms of the mutation of genes. New forms arise because the genes mutate. Undoubtedly this is part of the truth. The possibility of life depends on the existence of certain complex physico-chemical compounds. It is reasonable to suppose that the origin of new forms must depend upon their reorganization into new complex compounds. Furthermore, new forms cannot establish themselves unless these complex physico-chemical materials in the germ cells pass them on to the next generation.

But to know that a reorganization in the chemical components of the germ cells is necessary for the evolution of new forms is not to have proof that it is

[8] *Loc. cit.*, Ch. II.

sufficient. In fact we have very definite evidence that it is not. If the hereditary materials are not sufficient to account for the organization of an existent form, it seems to follow quite necessarily that they cannot be sufficient to account for the origin of new forms. The attribution of everything that occurs in evolution to the mutation of the genes, while partially correct as far as it goes, is entirely too easy a solution of the difficulty. It is too much like saying that it is due to abracadabra.

Specific knowledge is at hand which enables one to get a very much more accurate picture of the mechanics of evolution than this. Our previous remarks on the secondary status of the concept of time suggests the correct theory. Evolution is a temporal process. Since physics has revealed that time is relative and must be defined in terms of matter and motion, it follows that evolution must find its basis along with other processes in a physical and kinetic atomic theory. In fact, anyone who has sensed the physico-chemical character of life knows that this must be the case. Electrons and atoms cannot be the fundamental biological and physical concepts that they are if process is primary. Even Aristotle, who accepted a philosophy of becoming, saw this. Furthermore, if the problem in evolution is the origin of new forms, and form has its basis in an interaction between the raw hereditary materials within, and the environment without, it follows that we must look to the environment as well as the gene for the key to the process of evolution. Moreover, since the environment organizes the hereditary materials through the physiological gradient and the nervous system, it follows that the problem of evolution narrows down to a question of gradient and neural reorganizations with changing environmental influences and spontaneous or externally conditioned mutations of the genes. Certainly the science of geology assures us that such environmental changes occur. Moreover, Pike has been driven, by his own experimental findings in connection with the nervous system, to the conclusion that it is a most essential key to the origin of new forms in evolution.[15] In fact, the writer is greatly indebted to him for the first awareness of this aspect of the problem.

But traditional biology could accept this solution only by forgetting its physics. Pike has also reminded us that the genes cannot be reorganized nor can new neural organization be brought into existence without work being done upon them. This calls for energy. If the second law of thermodynamics is a literal temporal principle, what is the source of this energy? One can point to the fact that it comes from the sun, but this merely shifts the difficulty out of biology into astronomy, where it is usually ignored. Again we see how futile it is to talk about life without the philosophical attitude of mind which brings the findings of one special science into conjunction with the ideas of another. We discover also how important our analysis of the second law of thermodynamics,* and our new theory of first principles, is for biology. Both reveal that the second law is a physical and logical principle rather than a temporal process. And the macroscopic atom insures that there is a basic principle in nature inducing organization and providing spontaneously for the

* *Loc. cit.*, Ch. III.

organization of new forms, as well as the destructive disorganizing principle which Carnot discovered.

Given this source of energy, and changes in the environment or the genes, the reorganization of the nervous system follows. And considering the most organic character of living things, which Henderson's nomogram has revealed, it is unreasonable to suppose that radical environmental changes producing these radical internal reorganizations would not affect the complex organic compounds in the germ cells, especially since they are the key to the stability of the system. Certainly the organic character of living systems and nature puts the burden of proof on those who would assert the contrary. However, it also follows that no amount of external change will produce a new form unless complex compounds arise in the germ cells, which have precisely those properties necessary to enable the hereditary materials to grow by interaction with the environment into a new type which is stable. This is the truth expressed in the theory of the gene. As Henderson's nomogram indicated, not merely coordination but also complex chemical compounds are the key to the existence of life. Hence in evolution reorganization in the germ material and spatial and temporal environmental changes must go together. Evolution as well as organization has its basis in a merging of an external form-producing principle and an internal pluralistic kinetic microscopic principle.

Let us state this doctrine in more concrete terms. Consider that stage in the process of evolution when the animals left the water for eventual habitation on dry land. The problem which nature faced, if forms were to survive under the new environmental conditions, was to devise a new method of supplying the animal with oxygen. This problem was finally solved by laying down the wet membrane in the lungs between the circulatory system and the external atmosphere. Pike has indicated that such changes entailed the introduction of new nerves and a radical reorganization in the nervous system,[16] in which the center of control is shifted to higher and phylogenetically newer regions of the central nervous system.

How did this occur? To say that the genes mutated is certainly too easy an answer. Energy is necessary and it depends on external cosmic, rather than internal, local, factors. Furthermore, the nervous system is partially conditioned by external factors. There must be very powerful cosmic forces behind so mighty a reorganization. If the macroscopic atom is present to insure organization and is congesting the microscopic particles, certainly an externally imposed force working always for organization throughout nature is present. Furthermore, with a changed environment acting upon such a delicately balanced and sensitive physico-chemical system as a living organism, it seems reasonable to suppose that chance, or even, possibly, conditioned mutations might combine with external influences after many failures to produce a new organization. Certainly if there is a possible reorganization which will bring temporary organic equilibrium out of chemical flux, it seems inevitable considering the energy and time available, and the guidance of the physical principle of least work, that it must arise. Also when one recalls that external factors lay down physiological gradients, and that gradients determine the direction which

growing nerve tissue pursues, changes in the reorganization of the nervous systems are not so hard to understand.

There are two types of fact which make this account plausible. One appeared in connection with some experimental investigations of my friend and colleague, H. S. Burr.[17] Desirous of increasing the number of olfactory nerves for a certain experiment which he had in mind, he added some olfactory nerve tissue to the normal supply of a certain organism. He was surprised to find that in over 50 percent of the cases the transplanted tissue did not grow along the normal olfactory nerve path. Instead it wandered off through the brain case into the central nervous system by an entirely original route. He suggests that the explanation is to be found in Child's theory of the physiological gradient. Due to changed conditions at the time when the experiment was performed, the distribution of gradient differences was not the same as when the original olfactory nerve was laid down.* Thus a new physiological gradient arose to determine a new path for growing nerve tissue to follow. In any event we have experimental evidence that nerve tissue can develop in maturing differentiated organisms along entirely new lines.

A second relevant fact has been discovered by Coghill.[18] He finds that the growth of a nerve fiber through a distance no greater than one-hundredth of a millimeter is adequate to produce a change in neural organization sufficient to make the difference between a swimming and a walking animal. In other words, all that the environment needs to do in order to transform the neural structure of a swimming into that of a walking organism is to establish a difference in potential over a region no greater than one-hundredth of a millimeter in length. It is evident that very marked changes in neural organization can occur without any undue demands being made upon the principles of our physical theory. Both evolution and organization seem to be the product of an internal pluralistic permutative or mutative principle and a unitary externally imposed formal principle.

Of course, the traditional biological philosophy has suggested this idea in its doctrine of an environmental selection of the materials which mutations produce. The uniqueness of our theory centers in the new definition of environment which it provides. According to traditional theory, environment meant nothing more than the mere sum of all the local systems of nature; it was an effect of microscopic atomic motion, and in no primary sense a real cause. According to the macroscopic atomic theory environment is the sum of all the local systems of the whole of nature plus an order and organization imposed upon them by the macroscopic atom. Thus the environment is not a mere effect of atomic motion, there is an element of the causal in it also. Hence it conditions new forms as well as selects them from chance mutations. This also gives a basis for the notion of selection in the doctrine of natural selection. Although traditional biological philosophy used the latter doctrine, it was never really entitled to it; accepting only the microscopic atomic principle, it had but the principle of chance variations. Failure to define what it meant by environment covered up this fallacy.

* Recent experiments completed by Burr since this paper was read and published have established this.

An additional characteristic of the nervous system must be noted before we have gained a complete general picture of the physiological nature of man. It appears that new forms arise in the process of evolution by shifting the center of control to higher and phylogenetically newer regions in the central nervous system. Hence man's cortical mechanism, coming as it does at the present end of a long series of reorganizations, represents a rather complicated structure.[19] In the reorganization which has developed nature has taken two rather opposite directions. On the one hand it has gained a certain amount of rigidity. This has been absolutely essential to preserve life. It exhibits itself in the constancy of the hydrogen ion concentration, in the control of respiration and bodily temperature, and similar factors. On the other hand nature has produced great flexibility in man, without this, learning would be impossible and our educational institutions would be useless. To gain this it has been necessary to break away from the simple reflex with its specific response for a specific stimulus.[20] Many types of response are ready in waiting for an emergency. The advantage of such a neural mechanism in the struggle for existence is obvious. An organism cannot lay down a new neural organization when a harmful stimulus appears. Hence the organism possessing a wide repertoire of modes of response has an advantage. Thus we find that the two polar principles—pluralistic permutability and monistic rigidity—exhibit themselves in the central nervous system of man. In him both the microscopic and the macroscopic foundations of nature come to articulate expression.

Such is the general physiological nature of man. Born of a synthesis of atomic opposites, he is a mixture of constancy and change. Grounded in the private compounds of his chromosomes and in the foundation of physical nature, he is at once here and everywhere. Mid-way between the melting pot of formless microscopic atomic flux and the mold of eternal rigid macroscopic physical form, he exists with one root of his nature in time and the grave of atomic dissolution and decay, and the other in eternity and the constancy of the form and order of macroscopic nature.

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EDWARD ELLERY,
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